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Nationwide Urban Runnoff Program - USEPA (United States Environmental Protection Administration, Washtenaw County, Michigan Evaluation of Urban Stormwater Runoff and Management Practices for Controlling Urban Stormwater Runoff

Environmental Control Technology Corp.
Ann Arbor, MI

Prepared for

Environmental Protection Agency
Washington, DC

Mar 83

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FINAL REPORT

Nationwide Urban Runoff Program - USEPA
Washtenaw County, Michigan

Evaluation of Urban Stormwater Runoff and Management Practices for Controlling Urban Stormwater Runoff

for

James Murray
Drain Commissioner
Washtenaw County
Ann Arbor, Michigan

and

The Southeast Michigan Council of Governments
Detroit, Michigan

By

Environmental Control Technology Corporation
Ann Arbor, Michigan

March, 1983

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Nationwide Urban Runoff Program - USEPA

Washtenaw County, Ann Arbor, Michigan

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Summary Report

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and
Management Practices for Controlling Urban Stormwater Runoff

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Introduction

The Nationwide Urban Runoff Program (NURP) was undertaken by the USEPA in connection with the 208 Program in order to assess the effectiveness and the cost of selected urban stormwater pollution abatement techniques-termed Best Management Practices (BMP's). Evaluating BMP's nationwide was the policy option selected by the USEPA as the most prudent method of developing the body of information needed to correct and prevent pollution from urban stormwater runoff. The 208 Program resulted in the collection of much water quality data, but very little information exists, or has been collected by 208 heretofore, on the cost and effects of water pollution control techniques. NURP supported the evaluation of selected BMP's throughout the country, and based on such evaluations, will determine which BMP's are cost-effective in a particular situation and at a given scale. This approach is yielding data which is comparable within and between geographic regions. A collection of information will be available at the conclusion of NURP which will provide guidance to Federal, regional, State and local agencies responsible for implementing the Areawide Water Quality Management Plans.

This project was the result of a grant to the Washtenaw County Drain Commissioner's Office, through the 208 planning agency (SEMCOG), from the NURP program of the USEPA. The blending of the goals of the NURP program with the findings of the 208 study and the interest and control of the Drain Commissioner over stormwater management and drainage systems presented a natural sponsoring team for the program.

The primary objective of this study was to evaluate the effectiveness of Best Management Practices (BMP's) in reducing the pollutant loads present in urban stormwater runoff. Four specific BMP's were selected for evaluation:

1) Surface Retention Basin

2) Surface Detention Basin

3) Natural Wetland

4) Runoff Ordinance

In addition to the primary objective, objectives of this study included estimation of the quantity and sources of urban runoff pollutants entering the Huron River in the study area, and assessment of the impact of these loads on water quality in the river with and without the use of BMP's. The findings of this report represents the efforts of a two year sampling program.

Study Area

The Huron River Basin is located in Southeastern Michigan and discharges directly to Lake Erie. The terrain represents a typical Michigan landscape with gently rolling topography. Soils range from sands to heavy loams. The average rainfall is 32 inches per year of which 3 to 4 inches occurs as snowfall. The average storm event is 0.3 inches. Summer storms are usually localized, convective in nature, intense and of short duration.

The section of the Huron River specifically being addressed in this study is the reach flowing through the City of Ann Arbor from Argo Dam to Geddes Dam. This reach of river is a mixture of free flowing water and a large impounded area created by Geddes Dam. The river discharges from Argo Dam and flows freely for approximately 3 miles before entering the Geddes impoundment. Geddes Pond is approximately 5 x 10^7 cubic feet in volume and is a significant feature of the river in the urban area. In this reach of the Huron River five major separate storm drains discharge stormwater runoff. The five drains; Allen, Traver Creek, Swift Run, Pittsfield-Ann Arbor, and North Campus are part of the study program with BMP's being located in three of these drainage systems. Each of these five drainage districts were monitored during this program and consequently specific descriptions of each drain were developed for the fixed site data base program for NURP.

The general land use in this portion of the Huron Basin is a combination of urban area and agriculture land. The urban area of Ann Arbor is primarily residential in character with a substantial amount of parkland spread throughout the city. There is very little heavy industry in the city. Commercial areas are located in the downstream area, in shopping malls, and along major arteries. The city has developed in this manner due to the strong influence of the University of Michigan. The major economic base in the city is in high technology research type companies and professional service organizations. Thus, overall the city is primarily a residential area with commercial areas to support the population of 110,000 and to provide office and laboratory type space.

As mentioned earlier, the BMP's are located on three of the five major storm drains that discharge into the Argo Dam -- Geddes Dam reach of the Huron River. The retention basin is located in the Pittsfield-Ann Arbor Drainage District, the wetlands is located in the Swift Run Wetlands Drainage District and the detention basin is located in the Traver Creek.

Drainage District

The retention basin in Pittsfield-Ann Arbor Drain Drainage District receives runoff from two large subdistricts, one to the north and one to the south and west. Each of these districts was monitored separately during the study. The south sub-district is approximately 31% of the total area and is the Western and Southern portion of the district. In this area is located a regional shopping center, a local airport, an industrial and research park, and much land devoted to "open" uses, i.e., farming, woodlots, and vacant. The watercourse providing drainage is open, but has been greatly channelized. There are five "wet" on-line retention ponds on the shopping center site, and another on-line "wet" retention pond on the drain downstream of the research park and airport, as well as being downstream of the shopping center. This sub-district contains the highest proportion of open space and the least percentage of impervious area.

The second sub-drainage area is the largest one, accounting for approximately 46% of the total area. This area lies in the northern section of the District and the flow from it is southerly. The drain is entirely enclosed. This sub-district is characterized by having older and more developed urban land covers than either of the other two sub-districts. Land uses include a major university, medium and high density residences, and some strip commercial.

The Swift Run Drainage District is approximately 3100 acres. The drainage area above the wetland is 1207 acres. The stream flows northeasterly from its origin in Section 15 of Pittsfield Township and is open throughout most of its course.

Land use in the upper portion of the district are open and agricultural in nature. The impact of urbanization begins with the City of Ann Arbor's 110 acre landfill located adjacent to the Drain immediately south of Ellsworth Road. Immediately north of Ellsworth Road is located a high density residential townhouse development.

The wetland has been acquired by the Office of the Drain Commissioner in order to incorporate storage and water quality improvement into the design of the project. From this point to the outlet of the drain at the Huron River the drainage district has been almost completely developed with urban, and residential uses. Commercial strips also occur south of the wetland. The impervious surface increases and the roads are paved with curb and gutter drainage (but no catch basins with sumps).

The Traver Creek Drainage District is made up of 4400 acres. The drainage area above the detention basin is 2300 acres of which 1860 acres are dedicated to agricultural land uses. From the detention basin to the outlet of the drain at the Huron River the majority of the drainage district is comprised of 1500 acres of parkland and 370 acres of high and medium density residential land uses. The watercourse flows continuously throughout the year although the very flat grade of the streambed north of the detention basin coupled with the previous, agricultural covers produces a stream of low velocity and with rooted vegetation growing up to the water's edge. Excepting road culverts, the stream is totally open.

Best Management Practices

The study area was selected based on the findings of the 208 program from the region which targeted this area as an urban non-point source problem area. The concern and effort of the Washtenaw County Drain Commissioner to address this problem resulted in the availability of the in place Best Management Practices (BMP's) evaluated during this study.

On-Line Retention Basin

Design Specifications

The initial design of the basin was to provide flood relief to downstream sections of the drain. However, the basin may also provide water quality benefits to the downstream area and Huron River. It was the objective of this study to obtain water quality data on the "as built" inherent capability of this basin to reduce pollutant levels occurring in the storm water entering the basin. Some changes in water quality were expected to occur due to sedimentation processes and possibly through biological activity.

The basin shape is illustrated in Figure I. Water enters the basin from the west and exists to the east. There are two main tributaries discharging to the basin. These tributaries join into a single entrance channel several hundred feet upstream of the actual basin entrance.

A permanent water elevation of 801 is maintained in the basin with a permanent storage capacity of 914,760 cubic

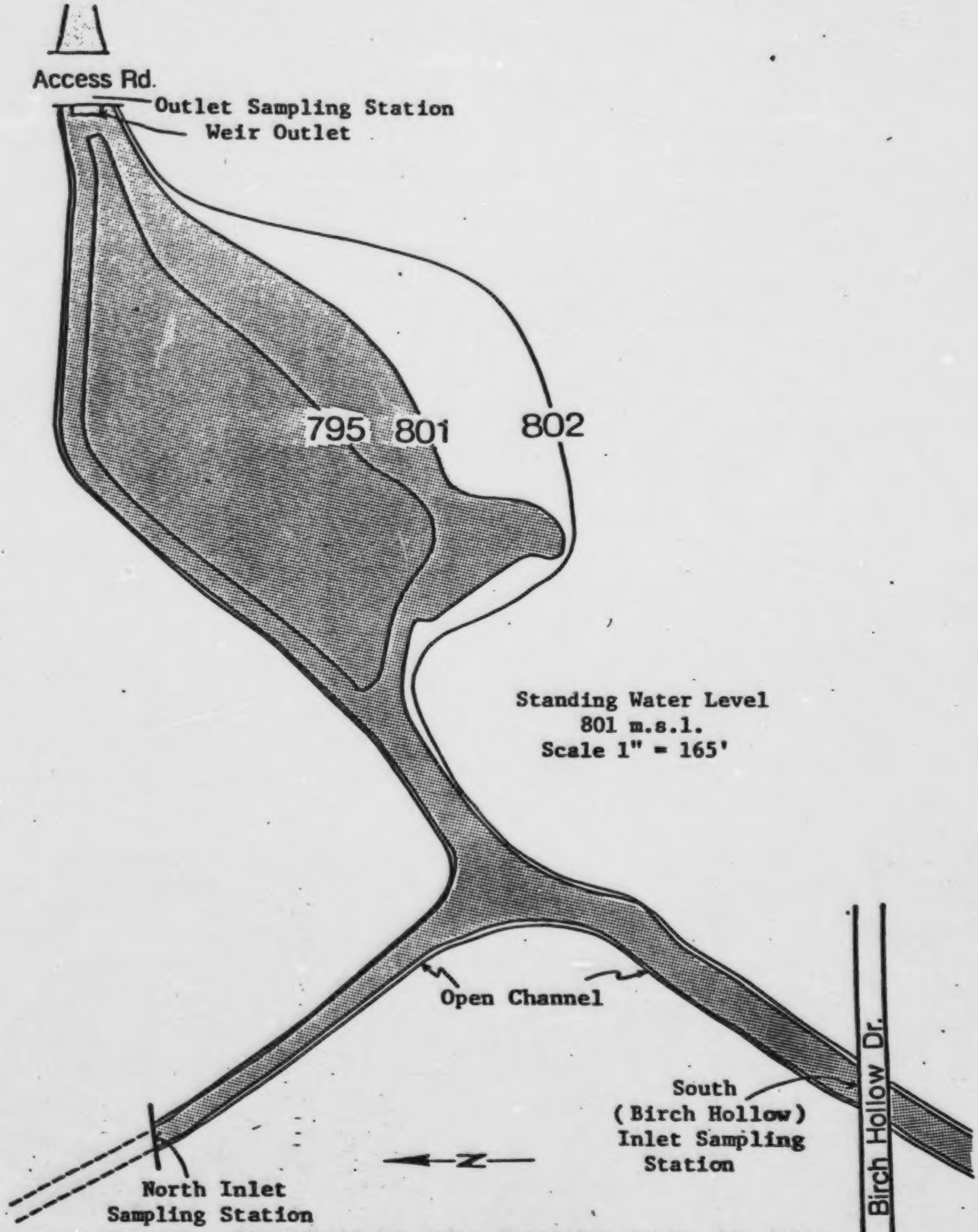

Access Rd.
Outlet Sampling Station
Weir Outlet
795
801
802
Standing Water Level
801 m.s.l.
Scale 1" = 165'
Open Channel
South
(Birch Hollow)
Inlet Sampling
Station
Birch Hollow Dr.
N
North Inlet
Sampling Station

Figure I. Pittsfield-Ann Arbor Retention Basin, Ann Arbor, Michigan

feet. An additional design capacity of 6,734,376 ft^3 occurs at elevation 807 with a maximum design flow of 2,916 cfs at this elevation. Depth-volume relationships are given in Table 1.

The outlet structure for this retention basin is a rectangular broadcrested weir which controls water elevation and discharge. This structure was designed only to attenuate flood flows and does not severely restrict flow at varying runoff rates. The overflow weir is approximately 60 feet in total length including both front and side surfaces. The depth of the water at the weir is approximately 1.5 to 3 feet measured during dry flow conditions.

Retention Basin Capital Costs

The construction of the Pittsfield-Ann Arbor retention basin and associated drain improvement projects was undertaken primarily in the construction seasons of 1977 and 1978. The costs of constructing the retention basin are shown in Table 2. These costs were based on the actual contractor costs as charged during the project. Land acquisition costs were reasonably high (approximately $12,500/acre) because of the location within a developed portion of the City. Engineering and legal fees were standard fees based on percentage of construction.

Table 2 Capital Costs Pittsfield-Ann Arbor Retention Basin

Land Acquisition	$128,750.00
Construction Costs	$186,026.30
Engineering Fees, Legal	$ 20,000.00

Table 1. Depth-Volume Relationship

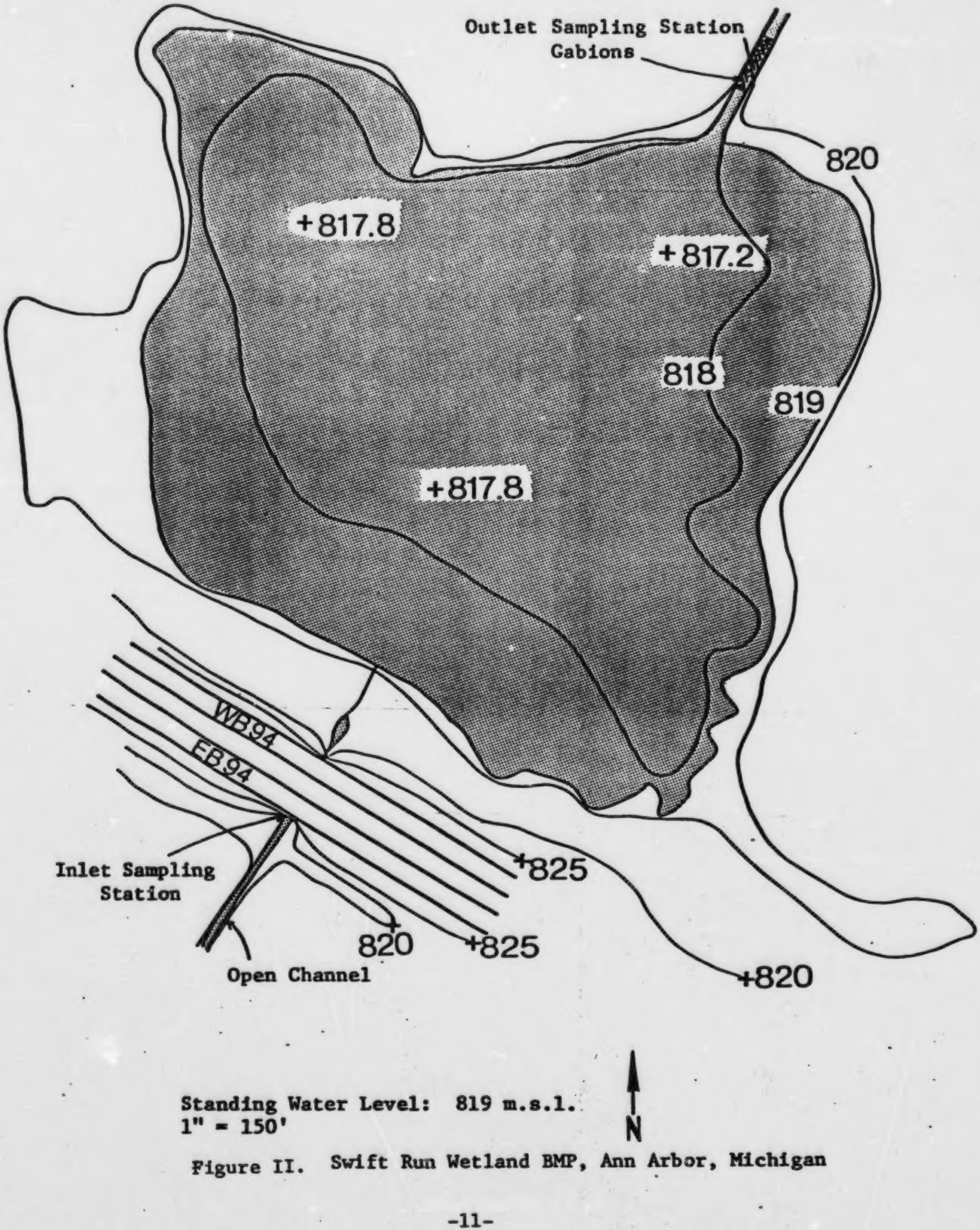
Elevation	Stage Feet	Surface Area (ft^2)	Capacity (cu.ft.)	Discharge (CFS)
801	0		914,760	0
802	1	226,510	1,141,270	198
803	2	383,330	1,681,420	561
804	3	588,060	2,678,940	1,031
805	4	834,175	4,251,460	1,587
806	5	1,048,900	6,159,384	2,218
807	6	1,122,400	7,649,140	2,916

Natural Wetlands

Design Specifications

Natural wetlands have the ability to accomplish many of the stormwater management objectives of artifically constructed retention basins. Wetlands can reduce stormwater velocity and buffer peak flows so that pollutants can settle out and also offer tremendous flood control abilities. Besides offering ways to improve the quality of stormwater runoff, wetlands also provide fish and wildlife habitats, recreational opportunities and aesthetic beauty. This naturally occurring wetland was investigated as a BMP for its capability to reduce total suspended solids, BOD, nutrients and metals contained in stormwater runoff from the upstream townhouse development and landfill.

The shape of the wetlands is illustrated in Figure II. The average depth ranges between one and two feet. The wetlands is designed to sustain a permanent water elevation of 819 with a permanent overflow structure which will handle flows generating heads up to 3 feet or elevation 822 (See Table 3). This yields a storage volume of approximately 2.6 x 10^6 cubic feet. This storage volume is sufficient to maintain outlet flows from the wetlands at rates equal to or less than 160 cfs., the capacity of the downstream storm sewer during a 25 year, 24 hr. duration rainfall. The controlling outlet structure is a trapezoidal weir with gabions lining the sides and bottom of the channel.


Outlet Sampling Station
Gabions
820
+817.8
+817.2
818
819
+817.8
WB94
EB94
+825
Inlet Sampling Station
820
+825
Open Channel
+820

Standing Water Level: 819 m.s.l.
1" = 150'

N

Figure II. Swift Run Wetland BMP, Ann Arbor, Michigan

Table 3. Depth Volume - Discharge Relationship Swift Run Wetlands

Elevation	Stage Feet	Discharge CFS	Volume (cu.ft.)	Surface Area Ft.^{2}
819	0	0	630,000	419,900
820	1	16	927,500	615,800
821	2	66	1,647,200	823,500
822	3	166	2,621,000	1,077,000

Natural Wetlands Capital Costs

The Swift Run Wetland was a natural wetland which originally outlet via a natural drainage course (creek). The only construction required at the wetland was the building of a control structure at the outlet. The control structure was required to provide flood relief for downstream areas by utilizing the full capacity of the wetlands. Bank improvement around the new outlet structure was also required to prevent overland flooding at high stage levels.

Table 4 shows the capital costs associated with the wetland improvement project. The construction costs for the outlet were based on actual cost to build the structure plus bank improvements. As shown in Table 4, the land acquisition costs was the major item in the budget. The wetland area was part of very large lots on which homes had been built on the higher area of each lot. Thus, it was necessary to purchase land from several owners in order to control the wetland area. The payment to these land owners was the major cost of the project. Legal fees were also quite high for this project due to negotiations with some of the land owners. It was necessary to carry out condemnation proceedings to obtain a few parcels of land.

Table 4 Capital Costs
Swift Run Wetlands

Construction Costs		
Outlet Structure		$ 33,750.00
	Total	33,750.00
Land Acquisition		101,000.00
Engineering and Legal Fees		15,000.00
	Total	$149,750.00

NOTES: Only construction required was outlet. Wetland was naturally present

Legal fees were high because of condemnation procedures needed to acquire the land.

Surface Detention Basin

Design Specifications

The basin was originally designed to provide detention of water for flood control and water quality improvement by sedimentation. The basin was designed as an off line basin which received water during high flow periods via a diversion channel. During high flows, the capacity of an overflow structure located in the normal creek bed would be exceeded, resulting in water being diverted to the basin. The purpose of using this approach was to provide a dry basin during dry weather, allow for the maintaining of normal dry weather creek flows, and to allow for increased holding time in the basin of the high flow waters by severely restricting the flow from the basin.

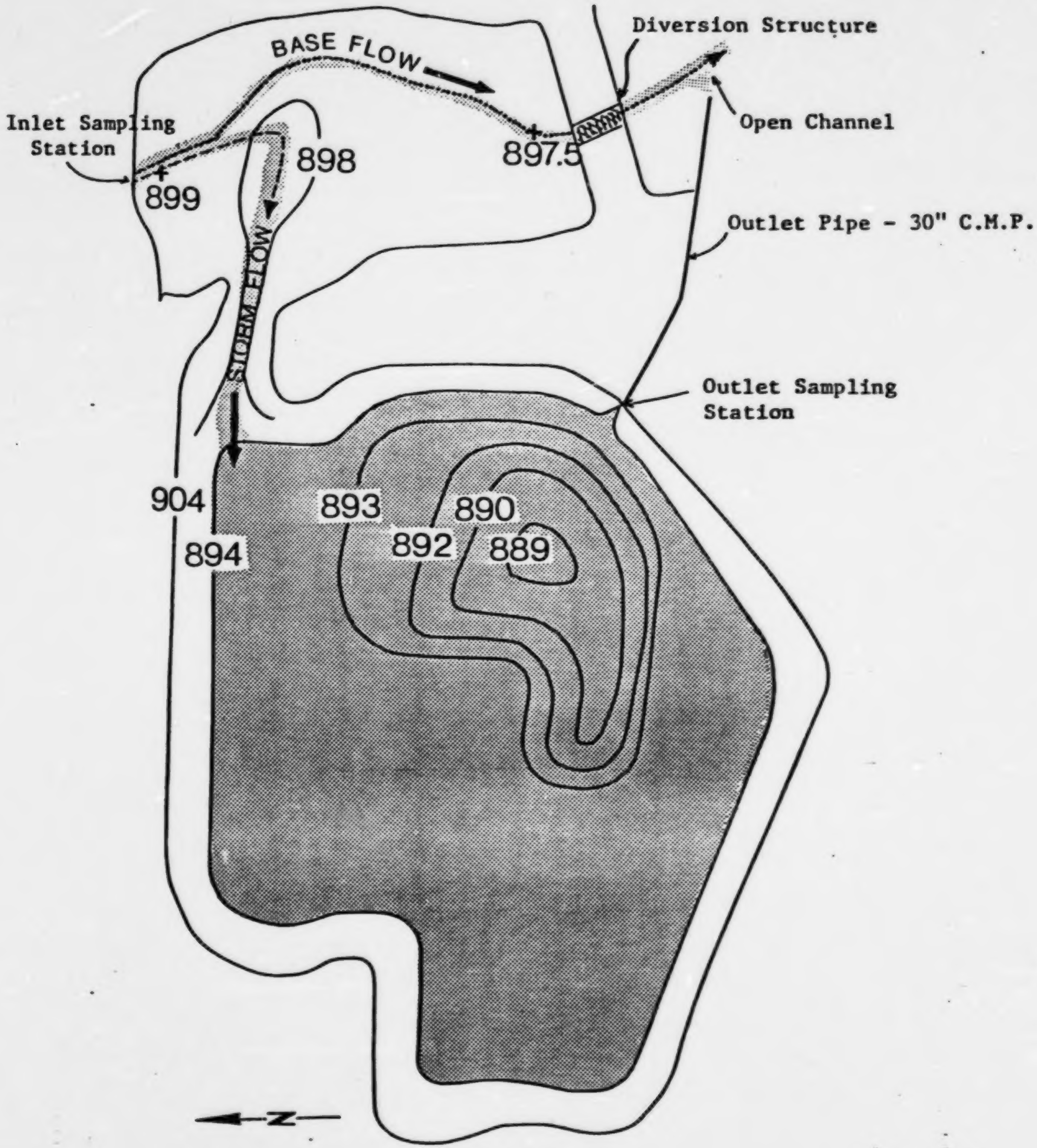
Several factors changed the original basin design and affected the basin conditions. The most important factor to this study was the construction schedule. Construction of the basin and outlet structures had been started in 1980 but due to delays in construction was not completed until late in the summer of 1981. These delays forced modifications in the BMP sampling program. By March of 1981 the bypass structure was the only item that needed to be completed. The drain had been rerouted by means of a temporary ditch directly into the basin. Since the bypass structure was not scheduled to be completed until the end of the summer of 1981, it was decided to monitor the basin as an on-line retention basin. No construction activity took place during the actual monitoring period (April-June). The objective of the evaluation of this basin was to determine the level of water quality improvement which could be expected from this type of on-line basin even though in this case the basin when completed would act as an off-line retention basin. The depth-area volume-discharge relationships for this basin using the actual conditions observed during the project are presented in Table 5. Figure III shows the general shape of this basin.

Table 5. Depth Volume - Discharge Relationship
Traver Creek Retention Basin

Elevation	Stage Feet	Discharge CFS	Volume (cu.ft.)	Surface Area Ft.
894	0	0	512,000	290,000
896	2	5.8	1,116,000	308,000
898	4	6.7	1,756,000	326,000
900	6	10.2	2,432,000	344,000

Traver Creek Retention Basin Costs

The Traver Creek retention basin is located in a former gravel pit area. The location and topography necessitated a large amount of earth work in this area. The basin area and outlet structures were designed for the 1 in 200 years storm due to requirements by the Michigan Highway Department. This design basis is for a much larger event than is normally considered for urban flood control. In addition, because the original design was for a dry off-line basin, a second control structure to maintain base flow in the creek was required. These factors should be carefully considered when reviewing the cost figures and will undoubtedly require adjustment if these costs are applied for other areas.



Diversion Structure
BASE FLOW
Inlet Sampling Station
898
899
897.5
Open Channel
STORM FLOW
Outlet Pipe - 30" C.M.P.
Outlet Sampling Station
904
894
893
890
892
889
N

Standing Water Level: 894 m.s.l.
1" = 150'

Figure III. Traver Creek Detention Basin, Ann Arbor, Michigan

Table 6 shows the construction costs and other fees for the basin. The construction costs were based on the bid documents for the project. Engineering and legal fees were based on a percentage of the total project costs. No land acquisitions costs were required for this project as the land was owned by the government.

Table 6. Capital Costs Traver Creek Retention Basin

Construction Costs	$229,515.00
Engineering Fees, Legal	$ 23,000.00
Land Acquisition	0

Monitoring and Analytical Program

General

The selection of water quality sampling stations and water quality analyses to be performed was based on the objectives of monitoring the inputs of the various drains to the Huron River, determination of water quality in the river during and following storm discharges, and the measurement of water quality conditions into and out of the various BMP's under investigation. Five stations for the measurement of flow and collection of composite water samples were established at the outlets of each of the five drainage districts discharging into the Geddes Pond Area of the Huron River. In addition, two stations were established on the river itself one upstream of the drains at Argo Dam and one downstream at Geddes Dam. Water quality monitoring stations were also established on the two inlet tributaries to the Pittsfield-Ann Arbor retention basin, on the outlet from the basin, on the inlet and outlet of the Swift Run Wetlands and on the inlet and outlet of the Traver Creek Retention Basin BMP's.

River and Drain Outlet

Sampling stations were established at the outlets of each of the five main drains entering Geddes Pond (Spring 1979). The stations were located as near the mouth of the drain as possible without being influenced by backwater effects. This was possible for all drain outlets except Allen Drain where the low flow was affected by the cycling of Argo Dam. A rating curve was established to account for this problem and at higher flows during a storm the backwater effects were negligible. Each station consisted of a continuous level recorder and a Manning automatic sampler for taking discrete samples. Equipment was housed in steel boxes for security. Float switches were used to activate the sampling equipment. All of the drains were open drains with the exception of Allen Drain which is an enclosed system. In each case the flow monitoring station was established at a bridge or culvert so that a predictable cross sectional area was available.

The sampling stations for the river were established at Argo and Geddes Dam. Automatic sampling equipment was placed on the dam structure and samples were collected where the water passed through the dams. Level recording equipment measured water elevation changes which were utilized in conjunction with design rating curves to determine flow. A U.S.G.S. monitoring station is located just downstream of Argo Dam which served as a check on the flow data.

BMP Monitoring Stations

Monitoring stations were established at the inlets and outlets of each BMP to obtain flow and water quality data.

Water quality samples were collected using automatic sampling equipment on a time basis. Discrete samples were collected at fifteen or thirty minute time intervals. Flow data, obtained from continuous level Stevens recorders, was then used to composite the discrete samples on a flow proportionate basis. One exception to this, however, was the Swift Run Wetlands Outlet where a Manning flow recorder automatically pulsed the sampler for a flow proportionate sample. Generally, for the rainfall events, one to two composites were made to represent the major runoff portion of the event, and one or two additional composites were made to represent the tail portion of the curve and background conditions. Thus, a series of sequential composite samples were obtained to represent each runoff event.

The flow data for the drains was obtained from the level recorders through the use of a developed stage discharge curve. The curve was based on a series of depth and velocity measurement taken over a range of flow during dry and wet weather periods. Water depths were manually read from the recorder charts and plotted or charted as flow-time relationships for each event.

Precipitation data was obtained from a continuously recording, weighing bucket rain gage. This rain gage provided both intensity and total volume of precipitation for each rainfall event. The gage was located approximately two miles from the retention basin and adjacent to the Swift Run Drainage District.

Analytical Protocol

The complete analytical program for this project is shown in Table 7. The results for selected parameters are given in this paper. Analytical methods utilized are approved USEPA methodology.

To ensure the reliability of the data base, a site specific quality assurance program was developed in addition to standard quality assurance procedures. Both field and laboratory procedures were incorporated in the quality assurance program. The main areas of the field quality assurance program included frequent calibration and verification of equipment specifications, periodic velocity and depth measurements to verify flow, collection of field blanks, duplicate samples and duplicate composite samples to check sample splitting techniques. Laboratory procedures included duplicate analyses, spiked samples, split samples, and performance evaluations of unknown samples provided by USEPA Region V.

Table 7. Monitored Chemical Parameters

Primary Analysis	Periodic Sample Analysis
Total Suspended Solids	Grease and Oil
Total Dissolved Solids	Total Cadmium
Particle Size Distribution	Total Zinc
pH/Alkalinity	Total Chromium
Nitrate Nitrogen	Total Nickel
Total Kjeldahl Nitrogen	Fecal Coliform
Soluble Kjeldahl Nitrogen	Fecal Streptococcus
Total Phosphorus	
Soluble Phosphorus	
Chemical Oxygen Demand	
Biochemical Oxygen Demand	
Total Iron	
Soluble Iron	
Total Lead	
Soluble Lead	

Results and Discussion

Pittsfield-Ann Arbor Retention Basin

Results

Six rain events and one snow melt event were monitored during the study period. Summaries of selected pollutant loadings entering and leaving the retention basin are shown in Table 8. These summary tables are based on loadings occurring during the runoff period corrected for base flow levels. Thus, the levels represent the load due to runoff.

This correction for background level is important during small storms as will be discussed later. The loadings for each storm were calculated from the sequential flow proportional composite samples collected during each event. The sequential composite samples provided detail data on the various portions of the hydrograph but have been combined into total loads and average concentrations for this paper.

Continuous flow recording at each station provided a good description of the runoff characteristics from the two subdistricts entering the basin. The North subdistrict, a totally enclosed system, was fairly flashy with high peak flows and rapid return to baseflow conditions. The South subdistrict, an open channel drainage system with retention basins, exhibited tempered peak flows and a more broad hydrograph with a long tail portion.

An overall comparison of the flow data collected at the inlet stations and the outlet showed that the volume of

Table 8. Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County Michigan

Station	Date	Rain Inches	Runoff Volume 10^6 cu. ft.	Runoff Coeff	TSS lbs.	T-P lbs.	TKN lbs.	T-Fe lbs.	T-Pb lbs.
Inlet	06/30/79	2.25	3.9		23400	49	262	539	16
Outlet			3.9	0.10	13000	36	258	502	8
% Rem		0.25	0.53		44	27	4	7	50
Inlet	10/22/79	0.25	0.53		920	5.1	16	29	0.7
Outlet			0.59	0.13	500	1.2	16	17	0.2
% Rem					54	82	—	41	71
					11**	55**		21**	60**
Inlet	08/10/80	0.40	0.66		1500	4.0	30	31	1.0
Outlet			0.66	0.15	480	3.2	21	24	0.6
% Rem					68	20	30	23	40
					39**	0**	0**	5**	34**
Inlet	09/09/80	0.90	2.3		6500	21	150	230	< 11
Outlet			2.3	0.14	5700	18	135	210	1.2
% Rem					12	14	10	9	> 90
Inlet	09/17/80	0.67	27		7100	23	150	210	2.1
Outlet			27	0.23	5900	21	110	170	1.8
% Rem					17	9	27	19	12
Inlet	10/24/80	0.45	1.0		2950	15	44	110	2.0
Outlet			1.0	0.13	440	11	22	30	1.1
% Rem					85	27	50	72	> 45
					57**	17**	9**	52**	> 45**
Inlet	02/17/80	Snow Melt	12.4		75000	218	1300	1600	21
Outlet			11.5		54000	274	1100	1300	30
% Rem					27	—	15	19	—

**Unadjusted values include baseflow in load cal.

runoff water balanced quite well with inlet and outlet volumes within 10% for all measured events. Dissolved solids data was also compared to provide a basis for evaluating the sampling program and again balances were within 10% and generally better. Runoff coefficients calculated from rainfall and runoff data are shown in Table 8. As can be seen the runoff coefficients are fairly constant for the rain events. The higher values found in September 1980 can be explained by the weather conditions preceding these events. August 1980 was an extremely wet month and several large rain events occurred in September. Ground conditions approached saturation and were conducive to higher runoff rates. Individual rain intensities also appeared to influence the runoff volume as shown in the September 9 data when 0.9 inches of rain fell in a two hour period.

The overall removal efficiency of the retention basin for suspended solids ranged from 10-85 per cent. The removal efficiency appears to be highly dependent on a number of factors which include detention time, basin design, outlet structure design and baseflow concentrations. As shown in the October 1979 storm survey, a small rain will show low removal efficiency if total unadjusted loads are utilized. As an example, accounting for baseflow levels in calculating per cent removal, the October storm changes from 11% unadjusted to 54% removal of TSS. This is due to the relatively low loading of the storm and comparatively high baseflow concentrations. The background suspended solids level in the retention basin is in the range of 14-17 mg/l. This level of suspended solids is higher than is generally found in storm drains in the area during dry weather.

A summary of the particle size data presented in Table 9 shows a clear shift in particle size distribution between the inlet and outlet stations. The outlet station has a larger percentage of smaller sizes reflecting the settling of the larger particles in the basin as would be expected. In addition, a comparison of particle size distribution between the two inlet stations shows that the south arm inlet generally has a larger percentage of smaller particle size than does the north inlet. This would reflect the fact that the south arm has several retention basins upstream from the sampling point and settling and removal of suspended solids is already taking place in these upstream basins.

Total Kjeldahl Nitrogen removal varied from 0-50% when background levels were accounted for and were very low on a total load basis. Part of the reason for the lower removal can be explained by the fact that more than 50% of the TKN was in the soluble form.

Phosphorus removal efficiency varied greatly ranging from 0-82%. Measurements of soluble and insoluble phosphorus showed that most of the phosphorus was in the insoluble form. This would suggest that removal of phosphorus should coincide with TSS removal levels. However, no statistically significant relationship between T-P and TSS removal could be determined.

BOD and COD removal efficiencies were low (10-20%), however the levels of oxygen demanding materials were also relatively low (BOD 2-12 mg/l, COD 25-50 mg/l). These low levels are typical of Ann Arbor drainage systems. Grease and oil was not retained in the retention basin. This fact would indicate that the grease and oil do not adsorb to the suspended solids which are settling, but rather are surface oriented and carry over at the outlet structure.

Table 9. Range of Particle Sizes
Pittsfield-Ann Arbor Retention Basin

Station	Size	Ave	Min - Max
	Micron	% wt	% wt
North Inlet	> 60	10	0-20
	4-60	70	40-90
	< 4	20	5-60
South Inlet	>60	10	0-25
	4-60	65	50-80
	< 4	25	20-50
Outlet	>60	0	0
	4-60	58	30-70
	< 4	42	30-70

Heavy metals results shows that metals do settle out consistently. However, the removal efficiencies do vary. These variations in removal efficiencies can be associated with the variations seen in the total suspended solids removals. In general the metals are mostly in the insoluble form and would be expected to be associated with and influenced by sedimentation processes. Long settling times in the basin result in better removal efficiencies as is true with total suspended solids removal. Lead has the greatest and most consistent removal efficiencies among the heavy metals monitored.

The results of the fecal coliform monitoring program indicate that the retention time in the basin is not long enough for coliform die off to occur. Coliform levels that enter the basin usually leave at similar concentrations. Ranges of fecal coliforms levels are shown in Table 10.

Examination of the snow melt data shows that runoff during snow melt periods contribute large quantities of pollutants to both inlet branches of the Pittsfield-Ann Arbor Retention Basin. Table 8 summarizes the pollutant loadings found during the February 1981 snow melt event. This was the major snow melt of the winter after which most areas were clear of snow. The data indicates that the retention basin does have some removal capability for all parameters monitored with total suspended solids and total iron having the highest removal efficiencies. Particle size data indicates that generally snow melt runoff contains larger particle sizes overall in comparison with rain event survey periods. This would tend to indicate that snow melt runoff may be more effectively controlled by sedimentation than rainfall runoff waters. As seen in rainfall events, total kjeldahl nitrogen is present more in the soluble form, whereas the metals are prevalent in the insoluble form. Soluble phosphorus is also slightly more prevalent than insoluble phosphorus during the snow melt period. Fecal coliform levels are found to be low for both inlets and resulted in the low levels of the range shown.

Comparing event mean concentrations (EMC's) of the snow melt event to the rain event's indicate that on the South Arm inlet the EMC's for most parameters (TDS, TSS, TKN, SKN, TP, SP, COD, T-Fe, S-Fe) monitored were considerably higher during the snow melt than found during the rain events. However, this was not found to be the case on the North Arm inlet. Event mean concentrations on the North inlet for the snow melt tend to be in the same range as those monitored during the rain events. A summary of the concentration's is shown in Table 10.

Discussion

It was anticipated that removal of pollutants in the Pittsfield-Ann Arbor retention basin would primarily be accomplished by sedimentation of suspended materials. The principle factor which affects sedimentation efficiency under ideal conditions is the detention time provided in the basin. In an ideal basin the detention time will determine the critical settling velocity. All particles having settling velocities higher than the critical value will be removed from the basin. However, many real world factors affect the actual performance of a basin and the magnitude of the deviation from ideal conditions will determine the actual efficiency achieved.

Table 10. Range of Inlet and Outlet Event Mean Concentrations Pittsfield - Ann Arbor Retention Basin

Parameter		Min	Max	Ave	Events
TSS (mg/l)	South In	23	102	53	7
	North In	41	136	70	7
	Outlet	22	75	40	7
TP (mg/l)	South In	.04	.33	.13	7
	North In	0.16	0.5	.26	7
	Outlet	.07	.38	.17	7
TKN (mg/l)	South In	0.5	1.9	1.0	7
	North In	0.7	1.4	1.1	7
	Outlet	0.7	1.6	0.9	7
T-Fe (mg/l)	South In	0.8	2.1	1.4	7
	North In	1.1	2.9	1.9	7
	Outlet	0.8	1.9	1.2	7
T-Pb (mg/l)	South In	.003	.02	.01	7
	North In	.02	.07	.04	6
	Outlet	.01	.04	.02	7
Fecal Coliform Cfu/100 ml					
	South In	1100	300,000		20*
	North In	1100	2,900,000		20*
	Outlet	1000	740,000		20*

*Total number of individual samples

Table 11 shows the average and minimum theoretical detention time (based on volume displacement) in the retention basin for each of the monitored runoff events. Peak suspended solids concentration, the event mean concentration, and overall percent removal levels are also shown. Suspended solids data are provided as this parameter is the primary constituent influenced by sedimentation. Other materials in the particulate form will follow the suspended solids levels to some degree depending on the size and specific gravity of the particles with which they are associated.

The performance of the retention basin (based on % removal of the total load) is lower than was initially projected using ideal basin assumptions at the beginning of the study. Several factors appear to be influencing the actual performance of this basin including site specific conditions and the basin design. Site specific conditions need to be understood and accounted for when using the results of this work in other applications. Basin design factors can be altered in future basin designs to improve the basin performance.

Two main factors, background suspended solids and other pollutant concentrations, and the particle characteristics for this drainage system, directly affect the percent removal levels measured for the basin. Using the ideal basin approach it would be expected that during smaller storms with lower peaks and average flows (i.e. longer detention times) that the performance of the basin on a percent removal basis would be the highest. However, as shown in Table 11, the October 1979 storm which was a small event, had the lowest overall percent removal. The calculation of this removal percentage, however includes all

Table 11. Detention Time for Monitored Events
Pittsfield - Ann Arbor Retention Basin

Date	Min. Detention* Time (hrs.)	Ave. Detention* Time (hrs.)	% TSS Removal	Peak TSS Conc. (mg/l)	Event Mean TSS Conc. (mg/l)
Snow Melt 1981	2.5	3.7	27	110	75
06-30-79	2.5	23	44	79	51
09-11-80	2.6	19	10(26)**	52	47
09-17-80	4.6	15	17(14)**	40	34
10-24-80	7.3	32	57(87)**	24	22
08-10-80	7.7	36	39(70)**	28	27
10-22-79	37	105	9(45)**	43	27

*Theoretical time based flow rate and volume displacement.

**Background corrected.

of the load during the monitoring period including both the background suspended solids level and the increase load during the storm. In the case of small storms, the background level in the retention basin (12 mg/l TSS) is a significant load compared to the event mean concentration of 16 mg/l for the October storm. Recalculating the removal efficiency for this storm by subtracting normal background levels results in a removal efficiency of 45%. Other pollutant removals are also impacted by background levels. The impact background concentrations have for these other parameters is shown in Table 8.

The impact of the background levels highlight that when examining and reviewing the rain event runoff data, care must be taken not to place too much emphasis on the actual percent removal of various materials but rather consider the removal amounts and types of mechanisms affecting the materials controlled.

A site specific condition of the South Arm inlet which effects both the total load during events and the background level, is that other retention basins upstream will tend to reduce the amount of pollutant which is available for removal. The north arm has no control on it and thus represents the total load coming from that drainage area. The south arm drainage area (2001 acres - 21% impervious) includes a large shopping center and airport but also contains several retention basins controlling the runoff from these developments. Based on land use characteristics and findings during the drain outlet survey and previous work, the runoff water from the south arm would be expected to be at least as contaminated on a concentration or per acre developed basis as the north arm area (2871 acres - 26% impervious). Examination of the data, however, shows that there is a dramatic difference between the event mean concentrations in the south arm and the north arm districts (Table 10). Event mean concentrations for suspended solids, total phosphorus, and total lead are lower in the south arm. It is quite apparent that the retention basins upstream are removing materials from the south branch. Thus much of the pollutant load, in the south arm, especially during small storms, has already passed through basins similar to the one under study. Therefore, it can be expected that the percent removal of total load in this basin will be lower than if all the water entering the basin was directly from the land.

Another factor which affects the actual performance of this basin is the particle size distribution (actually measured by settling time) present in the inlet waters. It was originally anticipated that a large fraction of the suspended solids in the runoff waters would be in the upper ranges above 62 micron. The actual data collected shows that the sizes tends to be smaller and thus require longer detention times to settle from the water column. In general, all of the data collected during this study tends to show a larger portion of the particles are in the smaller ranges. The south inlet location is further impacted due to the presence of the upstream retention basins. The distribution of the particles directly impact the removal efficiencies. As the distribution moves toward the smaller sizes longer detention times will be required to maintain a target efficiency level.

The design of a retention basin and the flow conditions of urban runoff have an important impact on the performance of the basin. As mentioned previously, the Pittsfield-Ann Arbor retention basin was not designed to optimize sedimentation, as the original function of the basin was for flood control. The outlet structure for the basin is a concrete broadcrested weir which is relatively short in length, and the bottom of the basin slopes upward toward the weir resulting in only a two foot water depth at the outlet. These conditions results in high velocity contours near the outlet, particularly during the high flow periods, and the potential for scouring of material near the outlet structure.

Stormwater flows are highly variable in nature and thus tend to cause very unsteady flow patterns in the retention basin. This deviation from the "ideal basin" will generally result in reduced performance due to short circuitry, disruption of smooth settling profiles and possible disturbances in the sludge zone. In addition, the data collected during this study indicates that the highest levels of suspended solids tend to occur during peak flow rates. Thus, the highest loads are entering the basin during the shortest detention times and least ideal conditions. These general stormwater characteristics and specific basin design conditions were considered in evaluating the performance data.

Comparing the detention time conditions and suspended solids levels (Table 11) shows several trends in the data. The peak suspended solids levels, event mean concentration, and removal percentages were ranked according to the peak flow/minimum detention time and average detention of each storm. Both peak concentration and event mean concentration followed a decreasing pattern as a minimum detention time increases. In addition, the percent removal of suspended solids tends to increase with increasing minimum detention time (i.e. smaller peak flows). These trends do not appear to hold for comparisons with average detention time which is based on average runoff flows. This data suggest that the peak flow rates are a significant controlling factor in the performance of the basin.

The dependence of the basin performance and event mean concentrations on the peak flow conditions rather than average conditions appears to be the results of the importance of the peak load quantities to the total load, the increased potential for short circuiting during high flow periods, and scouring at the outlet due to the high discharge rate. The event mean concentration for the runoff events when ranked with peak suspended solids concentration show that the event mean concentration is strongly influenced by the peak flow level. This factor tends to hold for varying storm types with different rates of peak to average flow. The combination of high flow and high concentration results in a significant percentage of the total load for the event leaving the basin during that period and consequently raising the overall mean concentration for the event. For storms such as those in in June, 1979 and September 11, 1980 which had high peak to average flow ratios (9:1 and 7:1 respectively) the event mean concentration was raised due to the sharp peak rate. Thus, when a comparison of event mean concentration to average detention time was made, the event mean concentrations did not follow the same trend as the other events of more similar peak to average ratios (2-4:1).

The influence of peak flows on the discharge of suspended solids from the basin would be expected during those periods when detention time is quite small such as snow melt and September 11, 1980 events (theo. min. detention time 2.5 hrs.). During these peak flow times, the suspended material has a much shorter period in which to settle and the most severe short circuiting and turbulance in the basin is probably occurring. High suspended solids levels are entering the basin at this time and some of the solids may be passing through the basin in a much shorter time than the theoretical time of 2-3 hours. This situation can be expected based on the mechanisms involved in the sedimentation process in a dynamically loaded system. However, the increase in concentration also occurs for storms where the peak flows are not as high and the minimum detention time is in the range of 7-8 hours (August 10, October 24, 1980, Table 11). For these events the highest concentrations occurred during the peak flow period even though it is highly unlikely that the load entering the basin had reached the outlet structure. This suggests that scouring is probably occurring at the outlet, resulting in high concentrations during the peak discharge period. Thus, even though the runoff load entering the basin may be settling to the bottom, previously deposited material near the outlet is being flushed from the basin. As a result, the performance of the basin is less than would be expected and the peak flow becomes a controlling factor in the performance of the basin for these storms also.

Based on this evaluation, several possibilities exist for improving the efficiency of retention basins in trapping suspended material. The problem of scouring can be minimized by adjustments in the outlet conditions. Deeper water depths coupled with better control of peak flows or providing a more distributed discharge would help minimize the scour problem. Further the data would indicate that control of the peak flows may be one of the most important factors in the efficiency of a retention basin. Outlet structures which lower the maximum outlet rate could provide better removal during the peak periods. Slowing the discharge rate will lengthen the detention time in the basin for the peak load periods and thus improve removal efficiency. Another possibility is increasing the size of the basin which will tend to dampen the peak to average flow rates, and will provide additional detention time in which settling can occur. The next section, describing the wetlands, is an example of a larger basin without a restricted outlet. The overall impact of the larger detention times raises the removal levels into the 70-90% range as will be shown.

In summary, the retention basin does remove suspended material from the runoff waters. Site specific conditions, particularly the impact of upstream retention basins, affect the actual percentage removal values for the basin. Higher percent removal values may be achieved in other areas without this influence. Peak flow conditions appear to significantly influence the basin performance and scouring is probably occurring on a regular basis near the outlet. Improvement in the performance of this type of basin could be achieved in future designs by attempting to minimize the scouring problem and improving peak flow control.

Finally, it should be noted tht even though the overall percentage removal levels for this basin may seem low (10-60) a large quantity of pollutants are being retained. For the seven events monitored during this study, over 36,000 pounds of suspended materials were retained in the basin.

Swift Run Wetland

Results

Five rain events and one snow melt event were monitored during the study period. Summaries of the pollutant loadings into and out of the wetland are shown in Table 12. The loadings presented include the total load measured (both baseflow and runoff) during each event. Loadings were calculated using the results from the flow proportional sequential composite samples collected during each event.

Hydrographs of the drain reflected the open channel conditions above the wetland with peak flows being moderately sharp and runoff duration lasting several hours after the rainfall ended. In addition, the very flat slope of the inlet drain and wetland itself tempered peak flows and slowed the water delivery to the wetland. Flow measurements were affected at the inlet by backwater. Therefore, most flow measurements were obtained from the continuous monitor at the outlet structure. Manual depth and velocity measurements at both the inlet and outlet were performed routinely to verify the flow data. Runoff coefficients have been determined for each runoff event and are shown in Table 12. As can be seen, the runoff coefficients vary more widely than for the retention basin, probably due to the influence of considerably more open area which will be more sensitive to soil moisture levels. Runoff levels increased for each April event in 1981 reflecting the very wet conditions occurring during that month of the study.

Table 12. Summary of Pollutant Loads
Swift Run Wetland
Washtenaw County Michigan

Station	Date	Rain Inches	Runoff Volume 10^6 cu.ft.	Runoff Coeff	TSS lbs.	T-P lbs.	TKN lbs.	T-Fe lbs.	T-Pb lbs.
Inlet	08/22/80	1.75	1.2	0.16	5300	13	75	110	1.3
Outlet			1.3		390	7	73	20	< 0.2
% Rem					93	46	3	82	> 85
Inlet	02/81	Snow Melt	3.8		20000	100	420	550	3.2
Outlet			3.8		11000	60	420	410	2.1
% Rem					45	40		25	34
Inlet	04/11/81	1.10	0.56	0.11	2900	4.9	36	38	0.34
Outlet			0.56		500	2.2	26	15	0.08
% Rem					83	55	28	60	76
Inlet	04/13/81	0.79	0.89	0.26	7800	10	74	110	0.68
Outlet			0.89		1700	5	56	50	0.09
% Rem					78	50	24	55	87
Inlet	04/22/81	0.88	1.2	0.30	4100	8	79	97	< 0.4
Outlet			1.2		770	3	59	53	< 0.08
% Rem					81	62	25	45	
Inlet	05/29/81	0.59	0.55	0.21	600	2	45	19	< .08
Outlet			0.55		150	2	33	4	< .04
% Rem					75		27	79	50

The removal efficiency of the wetlands for most of the parameters monitored is very good. Total suspended solids removal efficiencies ranged from 76 to 93 percent for the five rain events. Total iron and lead removal efficiencies are also good with most being greater than 50 percent as as high as 87 percent. Again, the iron and lead removal efficiencies are associated with the total suspended solids removals. These metals are mostly present in the insoluble form and therefore would be expected to be influenced by sedimentation processes.

Nutrient removal efficiencies vary between storm events. Some total kjeldahl nitrogen is removed (20-30% efficiency) although most of the kjeldahl nitrogen is present in the soluble form. Usually one would expect the concentrations of these dissolved material to pass through the basin unchanged. However, aquatic plant life present in the wetlands is probably utilizing some of this available nitrogen accounting for the removals seen. Total phosphorus on the other hand is removed fairly consistently with efficiency ranges of 40-60%. One exception to this is seen on the May 29-June 1, 1981 event where no removal is experienced and in fact some material seems to be exported. During this event over 50 percent of the phosphorus is in the soluble form in contrast to the other events where insoluble phosphorus is the major form present. During these events where insoluble phosphorus is the major form however, removal efficiencies ranging from 11-60 percent is experienced for soluble phosphorus. Again, this can probably be attributed to aquatic plant utilization.

The particle size data indicates that there is a small shift in particle size distribution between the inlet and outlet stations. Table 13 summarizes the particle size data collected for the six events. The outlet station has a larger percentage of smaller sizes reflecting the settling of the larger particles in the wetlands. However, it must be noted that this is a very subtle shift because of the large percentage of smaller sizes (< 4 u) entering the basin. Although data is limited, it appears before a new upstream retention basin (1981) was completed, large particles (< 4 u) made up a larger portion of the particles entering the wetlands. The 1981 event data (after completion of the retention basin) shows that most of the particles entering the wetlands now are in the range of 10 u and below. This would suggest that some settling of the larger particles is now occurring in the upstream retention basin. However, a comparison of total suspended solids event mean concentrations for the monitored events show no clear difference between the 1980 and 1981 events that would indicate the occurrence of extensive sedimentation in the upstream basin.

Table 13. Range of Particle Sizes
Swift Run Wetland

Station	Size	Ave	Min - Max
	Micron	% wt	% wt
Inlet	>60	5	0-10
	4-60	35	10-60
	>4	65	40-80
Outlet	>60	0	0
	4-60	25	10-50
	<4	75	50-100

Fecal coliform results for the August 1980 storm survey shows high levels of coliform entering the wetlands and significantly lower concentrations exiting the wetlands. However, the April and May 1981 events show no significant coliform levels reduction between the inlet and outlet stations. A summary of the levels is shown in Table 14. It should be noted that the coliform levels measured during the 1981 events are significantly lower than those measured during the one monitored 1980 event. Unfortunately not enough data is available to determine if these differences are in fact true conditions. Many variables exist that could account for the difference in these numbers including: time of year, water temperature and effect of the upstream retention basin. Additional sampling would have to be done throughout the summer and fall months to determine if indeed coliform concentrations are or are not affected by the wetlands and at what concentrations.

Examination of the snow melt data shows that runoff during a snow melt period contributes large quantities of pollutants to the Swift Run Drainage Basin. The snow melt event summary data is presented in Table 12. The event occurred in February, 1981 and was the main snow melt of the winter. As demonstrated in the summary tables the wetlands are still capable of removing pollutants but at lower efficiency levels than achieved during the rain events. This can be attributed to several factors, first of which is the tremendous volume of water passing through the wetlands in a fairly short period of time. Although event mean concentrations (Table 14) for the snow melt show that individual parameter concentrations are not greater for the snow melt than for monitored rain events, tremendous loadings into the wetlands (monitored at the inlet station) are being generated due to the large runoff volumes. In

Table 14. Range of Inlet and Outlet Event Mean Concentrations Swift Run Wetland

Parameter		Min	Max	Ave	Events
TSS	Inlet	17	139	74	6
mg/l	Outlet	4	46	18	6
TKN	Inlet	1.0	1.7	1.2	6
mg/l	Outlet	0.8	1.7	1.0	6
T-P	Inlet	.05	.42	.18	6
mg/l	Outlet	.04	.26	.10	6
T-Fe	Inlet	0.5	2.3	1.4	6
mg/l	Outlet	0.1	1.7	0.7	6
T-Pb	Inlet	< .006	0.02	0.01	5
mg/l	Outlet	< .001	0.009	0.003	6
Fecal					
Coliform	Inlet	500	120,000		19*
CFU/100 ml	Outlet	< 100	4,000		16*

*Total number of grab samples

addition, the wetlands at this time of year is not capable of utilizing any of the nutrient passing through in the runoff. Combining this with the fact that the settling time for the solids is reduced as indicated by the higher event mean concentrations measured at the outlet, the wetlands' removal efficiency mechanisms are definitely hindered during the snow melt period. Total suspended solids, BOD, COD, total and soluble kjeldahl nitrogen, total and soluble phosphorus and total iron event mean concentrations at the outlet are all considerably higher than those concentrations measured during the rain events.

Discussion

As in the case of the Pittsfield-Ann Arbor retention basin, it was anticipated that sedimentation would be a primary mechanism of pollutant removal in the wetland. The basic discussion of factors affecting sedimentation presented earlier for the Pittsfield-Ann Arbor basin also apply to the wetland. One additional potential benefit of the wetland is the removal of soluble materials by the aquatic plants in the wetland.

Table 15 shows the theoretical minimum and average detention time for the various runoff events. Suspended solids concentrations and percent removal levels are also shown. The performance of the wetland was quite good for the runoff events.

The data in Table 15 is ranked by increasing minimum detention time (highest to lowest peak flow). As can be seen, there is a relationship between detention time and peak suspended solids levels and basin efficiency (with the exception of the 8-20-80 event). The much shorter detention

Table 15. Detention Time for Monitored Events
Swift Run Wetland

Date	Min. Detention Time (hrs.)	Ave. Detention Time (hrs.)	% TSS Removal	Peak TSS Conc. (mg/l)	Event Mean TSS Conc. (mg/l)
Snow Melt 1981	9.3	12	45	70	46
08/20/80	20	33	93	8	5
04/14/81	21	53	78	46	16
04/22/81	24	48	81	22	10
04/11/81	43	67	82	19	15
05/29/81	54	82	76	9	4

times during the snow melt period resulted in higher solids levels at the outlet and a subsequent decrease in removal efficiency. Removal efficiency is higher for the longer detention periods, but appears to level off in the 80% range. There is little difference in the removal for minimum detention times beyond 20-24 hours or for average detention time beyond 48 hours.

As in the case of the Pittsfield-Ann Arbor basin, the peak suspended solids levels tend to follow the peak flows or minimum detention time. Event mean concentrations were influenced by peak levels but not as severely as in the case of the retention basin. The ratio of peak flow to average flow was much smaller and more consistent for the wetland system. Two factors affecting the ratio of peak to average flow are the size of the basin and the upstream drainage system. The wetland is much larger than the retention basin in terms of ratio of volume to typical runoff flow (i.e. longer detention times). This larger size dampens the peak flows and thus lowers the peak to average flow ratios. Dampening the peak flows results in a better settling condition in the basin and reduces the influence of the peak TSS concentrations. In addition, the upstream drainage system is all open channel and drains a relatively flat area. The peak flows are tempered by these physical conditions, thus reducing the stress on the wetland due to peak flow conditions.

The relationships between nutrient inputs (i.e., phosphorus and nitrogen) and the wetland response is somewhat different than the effects of suspended solids, BOD_5 and metals. The response of the wetland is very dependent on the season of the year. During the warmer months when growth is occurring in the wetland, phosphorus and nitrogen will be utilized by the plants. This process will concentrate the nutrients in the wetland area during the warm months, and thus reduce the concentration of nutrients flowing out from the wetland. With the onset of winter, however, the plants die and the nutrients which have been accumulating begin to be released and flow from the wetland. Thus, during cold weather nutrient levels leaving the wetland will generally be higher than incoming water. During a sampling program for the Drain Commissioner 1977 this effect was noticed in the winter sampling period when nutrient concentrations were higher at the wetland discharge point than the general baseflow levels in the drain. The wetland response to nutrient inputs thus changes the timing of when the nutrients reach the river rather than actually removing or reducing a large portion of the total nutrient load. This change in timing can be a benefit to the river as the nutrient load is delivered during cold months when the impoundments along the river are also releasing their nutrient loads. Thus, the immediate impacts on the river of nutrients released from the wetland will be less than during warm months when the greatest potential for severe water quality problems generally exists.

While much of the nutrient load will eventually reach the river, the wetland area may result in some actual reduction in nutrient load. Studies of wetland systems in Wisconsin have shown that phosphous removal in 0-30% range may be obtained due to permanent holding of phosphorus in the sediment. Some increased removal of phosphorus can be obtained by harvesting the plant material, but the Wisconsin studies indicted this represented only a small percentage (6%) of the phosphorus load. Some nitrogen reduction may also be obtained due to the reduction of nitrate by natural processes. This reduction is dependent on specific conditions occurring in the sediment and requires an anaerobic environment to occur.

Overall, the wetland provided good control of runoff pollutants for the monitored runoff events. The discharged water quality from the wetland was generally low in suspended solids (5-15 mg/l event mean), phosphorus and lead compared to normal urban runoff. The size of the basin provided this control over the entire size range of monitored rainfall events, all of which were higher than the mean rainfall event for this area. Thus, for typical rainfall events the wetland can be expected to produce an effluent of good water quality when compared with uncontrolled urban runoff or point source dischrges. Its interesting to note that during all of the rainfall events the water from the wetland was below the tertiary treatment levels set for the Ann Arbor wastewater treatment plant (10 mg/l TSS, 10 mg/l BOD_5, <1 mg/l T-P).

Traver Creek Retention Basin

Results

Five rain events were monitored during the summer of 1981. Summaries of the pollutant loadings into and out of the basin are shown in Table 16. The loadings presented include the total load measured (both baseflow and runoff) during each event. Loadings were calculated using the results from the flow proportional sequential composite samples collected during each event.

The removal efficiency of the retention basin for most parameters monitored is very low. Total suspended solids removal efficiencies on a mass load basis are less than 35 percent for all of the monitored events. Suspended solids are actually exported from the basin during the May 9-14

Table 16. Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

Station	Date	Rain Inches	Runoff Volume 10^6 cu.ft.	Runoff Coeff	TSS lbs	T-P lbs	TKN lbs	T-Fe lbs	T-Pb lbs
Inlet	04/11/81	1.10	0.73		1,600	3.7	37	24	< 0.06
Outlet			0.54	0.06	1,060	1.4	15	18	< 0.03
% Rem					34	62	59	25	
Inlet	04/13/81	0.79	1.47		5,100	13.1	75	110	< 0.14
Outlet			1.46	0.22	5,450	7.7	76	111	< 0.15
% Rem					0±10%	41	0±10%	0±10%	
Inlet	04/22/81	0.88	1.58		3,620	8.9	99	91	< 0.15
Outlet			1.36	0.18	3,040	6.7	71	91	< 0.11
% Rem					16	25	28	0±10%	
Inlet	05/09/81	0.83	1.13		646	4.1	58	28	< 0.05
Outlet			1.06	0.15	888	2.4	46	23	< 0.06
% Rem					(-37)	41	21	18	
Inlet	06/13/81	1.47	0.33		430	2.0	22	17	< 0.04
Outlet			0.30	0.02	323	0.77	14	8	< 0.06
% Rem					25	62	36	53	

rain event. This export of suspended solids is probably due to the unstable retention basin bank conditions that existed during the study period. The retention basin was just recently constructed and the sod along the banks had not stabilized all of the side walls yet. Some side bank erosion problems were noticed during the monitoring periods.

Metal removals, which are usually associated with suspended solids removal and the sedimentation process are also very low for the five rain events. Some total iron removal is achieved in three of the five events. Removal efficiencies of 26 and 50 percent for total lead are measured for two out of the five events. The remaining three events show no lead removal.

Particle size data (Table 17) indicates that there is not the characteristic downward shift in particle size groups between the inlet and outlet stations as seen in other retention basins. In fact, in some cases, greater percentages of larger particles are leaving the basin than had entered the basin. This indicates that either settling of the larger particles is not taking place in the basin or that some settling is occurring but erosion problems are introducing more sediment into the basin after the inlet station.

Parameters that do show consistent removal efficiencies are nitrates (10-61 percent) and total phosphorus with an efficiency range of 25-62 percent. Over 50 percent of the phosphorus present is in the insoluble form which would indicate that sedimentation is the mechanism for removal. However, soluble phosphorus is also being removed with efficiencies ranging from 58-79 percent. Both soluble and insoluble kjeldahl nitrogen also show removal efficiencies with ranges from 0 to 59 percent.

Fecal coliform data collected during three rain events shows that the coliform levels entering the basin are fairly low and that some die off is experienced in the basin as exhibited by the lower outlet concentrations. The long detention time in this basin (50-60 hrs.) appears to provide sufficient time for significant die away to occur.

Table 17. Range of Particle Sizes
Traver Creek Retention Basin

Station	Size	Ave.	Min-Max
	Micron	% wt	% wt
Inlet	>60	0	0-2
	4-60	57	30-75
	> 4	43	25-70
Outlet	>60	2	0-8
	4-60	38	30-60
	< 4	60	45-70

Discussion

The design of the Traver Creek basin provided good control of outlet flow and long detention times in the basin. Table 18 shows the minimum and average detention time during runoff events and the associated suspended solids concentrations for these events. As shown in the

TABLE 18

DETENTION TIME FOR MONITORED EVENTS
Traver Creek Retention Basin

Date	Min. Detention Time (hrs.)	Ave. Detention Time (hrs.)	%TSS Removal	Peak TSS Conc. (mg/l)	Event Mean TSS (mg/l)
6-13-81	54	130	25	20	18
4-11-81	57	65	34	40	31
5-10-81	60	75	+	16	13
4-22-81	62	69	16	63	36
4-14-81	63	65	x	68	60

+ - export of material
x - 0± 10%

table, long detention times are occurring in the basin and the peak flow (minimum detention) is well controlled for these size storm events. It would be expected, based on sedimentation theory and the other results of this study, that high removal efficiencies of suspended solids should be obtained in the basin. The data shows that this is not the case for suspended solids. Data for the phosphorus, nitrogen, and some metals does show some removal of these materials. This type of performance (i.e. nutrient removal, no solids removal) is contrary to the findings of the other portions of the study.

The probable reasons for the relatively poor performance of the Traver Creek basin appears to be due to site specific conditions rather than design problems or more widespread difficulties with the basic BMP approach. A primary cause of the high outlet levels of suspended solids appears to be due to unstable bank conditions and subsequent erosion near the outlet structure. Due to delays in the construction schedule, the basin itself was not completed until the Fall of 1980. Sod had been placed on the banks to stabilize the soil at that time. It was anticipated that erosion would not be a significant problem in the spring. Unfortunately, this does not appear to be the case especially during the April events.

In addition to the physical evidence that erosion problems existed, the data for other pollutants also tend to support this conclusion. Short circuitry of water through the basin was considered a possible cause of the poor performance for removing suspended solids. It was difficult to conceive that short circuitry would be so significant given the very long theoretical detention times (50-70 hours). The fecal coliform data taken at various times during the event shows that inlet concentrations of coliform did not appear at the outlet in the same time frame as would occur in short circuitry situations (see Table 19). In addition, phosphorus and nitrogen showed overall reductions in levels, with outlet concentrations being lower than inlet levels. This data would indicate severe short circuiting is not occurring. The nutrient removal occurring in the absence of suspended solids reduction would also indicate that the suspended material being discharged was different in character than the material entering the basin. This would be the case if side bank errosion was occurring during April.

The banks were visually more stable during the May and June events, and the concentration of suspended solids leaving the basin dropped considerably (13-18 mg/l). The inlet level of suspended solids also was lower, however, during these events (9-21 mg/l). In general, the inlet levels of the pollutants being monitored were quite low during the study period. This condition is another site specific condition which appears to have affected the performance evaluation for the basin.

The land in the drainage area above the retention basin is not highly urbanized and the drainage system is a natural open creek type system. In general, all of the concentrations of the various parameters were lower in this drainage area when compared to the more urbanized and densely populated drainage districts such as Allen and Pittsfield-Ann Arbor Drains. It had been anticipated that suspended solids levels would be high in this area during larger storm events due to inputs from the agricultural areas. However, this was clearly not true for this drainage district. The input of relatively low concentrations of

Table 19 Range of Inlet and Outlet Event Mean Concentrations Traver Creek Retention Basin

Parameter		Min	Max	Ave	Events
TSS (mg/l)	Inlet	9	54	31	5
	Outlet	13	60	32	5
TKN (mg/l)	Inlet	0.81	1.0	0.89	5
	Outlet	0.43	0.84	0.71	5
T-P (mg/l)	Inlet	0.05	0.14	0.09	5
	Outlet	0.04	0.08	0.06	5
T-Fe (mg/l)	Inlet	0.39	1.2	0.77	5
	Outlet	0.34	1.2	0.72	5
T-Pb (mg/l)	Inlet	< 0.0007	0.001	< 0.0009	5
	Outlet	< 0.0009	< 0.003	< 0.002	5
Fecal Coliform CFU/100 ml	Inlet	100	26,000		12*
	Outlet	78	5,500		12*

* Total number of grab samples

materials to the basin in the May and June events (after the banks appeared stable) resulted in little material being available for removal. This is a site specific condition which would not be the case in other urban areas or drainage systems.

The Traver creek basin was built in anticipation of an increased level of development and runoff in the upstream area. The basin design considered the conditions which are expected after the area has been developed. Based on the results for the other BMP's studied, it is anticipated that this basin will be very effective in controlling the urban runoff. Unfortunately, given the conditions which occurred during the study, the monitoring data can not strongly support this opinion.

Huron River

Results

The Huron River and five major drain outlets were sampled twice during this study. A snow melt survey occurred in February 1979 and a summer rain event was monitored in August of 1979. River sampling began on February 22 and continued until February 26 during the major snow melt. On February 23 the temperature rose to forty degrees (^{o}F) and sampling of the five drain outlets was performed. The weather turned colder on the night of February 23 and remained below freezing until February 26, 1979.

The pollutant loads (solids, nutrients and metals) measured in the drains are shown in Tables 20. In reviewing this data, it can be seen that the largest flow and loads

TABLE 20

Pollutant Loads
Snow Melt Survey
Ann Arbor, Michigan

February 23, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft.)	5,432	5,389	235	338	200
pH	(S.U.)	7.85	7.94	7.77	7.99	7.89
Total Dissolved Solids	lbs.	680,300	467,800	39,000	27,700	21,200
Total Suspended Solids	lbs.	70,000	39,000	1,300	3,400	700
Biological Oxygen Demand	lbs.	8,500	5,700	450	690	200
Total Kjeldahl Nitrogen	lbs.	1,400	500	32	50	22
Soluble Kjeldahl	lbs.	1,060	400	29	31	15
Nitrate	lbs.	700	400	36	37	8
Total Phosphorus	lbs.	170	63	2	5	1.3
Soluble Phosphorus	lbs.	47	10	0.6	1.7	0.1

TABLE 20 (Cont.)

Metal Loads
Snow Melt Survey
Ann Arbor, Michigan

February 23, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft)	5,432	5,389	235	338	200
Iron	lbs.	1,800	970	33	60	20
Soluble Iron	lbs.	13	3	1.2	0.4	0.4
Lead	lbs.	138	46	0.8	4.1	0.9
Soluble Lead	lbs.	2.7	0.7	0.07	0.12	0.02
Zinc	lbs.	193	64	2.6	5.3	0.7
Chromium	lbs.	26.8	19.1	0.4	0.8	0.2
Cadmium	lbs.	4.7	0.5	0.02	0.03	0.002
Copper	lbs.	33.9	12.8	0.3	0.5	0.2
Nickel	lbs.	10.8	3.4	0.2	0.5	0.09

are from Allen Drain followed by the Pittsfield-Ann Arbor Drain. This essentially follows the same pattern as the land use/cover for the drains with Allen Drain representing the heart of the city and Pittsfield-Ann Arbor the largest drain in the City. The flow from these two drains was substantially higher during this period. Observations indicated that this was due to the large amount of snow melted along the roadways which constituted a larger percentage of area in these two drains as compared with the other drains that have substantial amounts of open undeveloped areas in the upper portion of their districts. The melt event monitored here represented the first major and largest snow melt of the season and virtually cleared the main street area of snow. Thus, the high loads of Allen and Pittsfield-Ann Arbor Drains represent a major portion of the snow melt from impervious surfaces in these districts. The other drains were receiving runoff but not nearly as high a total amount in relationship to their size.

When looking at the snowmelt data on a pounds/acre basis, Allen Drain and Pittsfield-Ann Arbor Drain clearly show more runoff and loading per acre than the three other drains. These higher values per acre again reflects the more densely developed areas, greater imperviousness and more commercial/industrial land uses that are typical in these two drainage districts.

When examining pollutant loads entering and leaving Geddes impoundment during this snow melt period the following trends are observed. Removal efficiencies of over fifty percent are seen for total suspended solids, total iron, lead, zinc, cadmium, copper and nickel. These high removal efficiencies can be attributed to sedimentation processes occurring in Geddes Pond. Nutrient removal is not experienced although it would not be expected in parameters that are found mostly in the soluble state as is the case with kjeldahl nitrogen. Fecal coliform levels entering the river from the five drains are reduced considerably by the time the water passes through Geddes impoundment.

The summer water quality survey was performed during the period of August 17 through August 27. The pollutant loads measured in the drains are shown in Table 21. A general review of these tables shows that the highest loads are originating from the Allen and Pittsfield-Ann Arbor Drains. These higher loadings are not just due to the fact that the basins are larger, but these two districts generally have higher concentration of most pollutants and have substantially more runoff and load on a per acre basis. The higher runoff volumes per acre reflects the more densely developed areas, greater imperviousness, more commercial/industrial usage, etc. A good example of this is shown in the total suspended solids data. Allen and Pittsfield-Ann Arbor Drains discharged 14 pounds per acre and 22 pounds per acre of total suspended solids, respectively. Swift Run, Traver Creek and North Campus Drains discharged 2.3, 2.2 and 0.37 pounds of total suspended solids per acre. Another example of this loading difference between drains (i.e. land uses) is shown in the total lead data. Allen and Pittsfield-Ann Arbor Drains, both characterized by having a large amount of roadways, discharged 0.006 pounds per acre and 0.003 pounds per acre of lead, respectively. Traver Creek, Swift Run, and North Campus Drains discharged 0.0009, 0.0002, and 0.00006 pounds of lead per acre. The dramatic difference in these loading levels show quite clearly the impacts of land use and cover on pollutant loads. The loading differences for total suspended solids and lead can also be observed for other constituents such as phosphorus, nitrogen and iron.

TABLE 21

Pollutant Loads
Ann Arbor, Michigan

August 17-20, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft.)	7,705	10,685	832	1,973	145
pH	(S.U.)	7.8	7.8	7.7	8.0	7.8
Total Dissolved Solids	(lbs.)	134,000	195,000	15,000	57,000	3,000
Total Suspended Solids	(lbs.)	52.600	142,000	7,000	9,880	570
Biological Oxygen Demand	(lbs.)	1,900	1,800	110	430	36
Total Kjeldahl Nitrogen	(lbs.)	430	800	47	120	8
Soluble Kjeldahl Nitrogen	(lbs.)	172	270	15	77	4
Nitrate	(lbs.)	200	156	13	77	2.7
Total Phosphorus	(lbs.)	138	60	6	4	1
Soluble Phosphorus	(lbs.)	<5.1	<11	<0.52	<1.5	<0.10

TABLE 21 (Cont.)

Metal Loads
Ann Arbor, Michigan

August 17-20, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft.)	7,705	10,685	832	1,973	145
Iron	(lbs.)	920	3,310	180	200	16
Soluble Iron	(lbs.)	<16	28	2.2	3.1	0.28
Lead	(lbs.)	21	19	0.70	<4	0.10
Soluble Lead	(lbs.)	<0.48	<0.66	<0.05	<0.12	<0.01
Zinc	(lbs.)	96	95	7.7	18	1.1
Chromium	(lbs.)	7.1	9.7	1.6	0.87	0.11
Cadmium	(lbs.)	<0.18	<0.27	<0.02	0.06	0.002
Copper	(lbs.)	9.7	6.1	0.48	1.4	0.06
Nickel	(lbs.)	<1.0	2.8	0.23	0.35	<0.02

Composite samples of the Huron River from upstream (Argo Dam) and downstream stations (Geddes Dam) were collected over a ten day period. The data shows very little change in water quality at Geddes during and after the runoff period. The higher event mean concentrations for some parameters found at Geddes Dam when compared to values measured at Argo Dam illustrates the influence that the runoff waters do have on this reach of the river. Increases in total suspended solids, nutrients and total iron can be seen. The particle size data shows a slight shift in distribution reflecting the settling out of some of the larger particles in the basin. Summaries of pollutants entering and leaving the impoundment on a total load basis show removal efficiencies of over fifty percent for total suspended solids, total iron, lead, zinc, cadmium, copper and nickel. Removal of nutrients does not occur.

Discussion

It is evident from inspecting the survey data that large quantities of suspended solids are discharged from the storm drains and are retained within the Geddes Pond area. Both the snowmelt and summer surveys support this observation. The data indicates that 80-90% of the incoming solids loadings are retained in the pond. Heavy metals are also being held within the impoundment. Lead and iron, both measured in reasonably high levels, were held within the impoundment in high percentages (60-90%). During the snow melt period, phosphorus also was retained within the pond area while it appears that this was not the case during the summer period using the net mass balance approach.

Numerical water quality standards have been specifically established for lead (50 ug/l) and cadmium (10 ug/l) while suspended solids and nutrients have no numerical standards for comparison. Comparing the standards with projected pollutant concentrations in the Huron River during the snow melt and rain event shows that the lead standard is exceeded during the snow melt. Suspended solids levels are twice the guideline and phosphorus levels increase substantially over the background levels. The increases in these constituents occur only in the river during runoff periods which tend to be of short duration. Thus the exceedance of the standards and/or guidelines is a temporary situation. These short term levels of solids, nutrients and metals do not appear to result in immediate or acute water quality problems in the river during the runoff period. However suspended solids discharges do result in very turbid water and are an aesthetic nuisance problem following storm events.

The solids, phosphorus, and metals levels decrease following the storm events due to sedimentation in the impoundment. This results in the water quality of the river at the Geddes dam overflow being within the standards and guidelines for the various chemical constituent. Thus, it appears that present stormwater discharges do not result in severe water quality degradation in the river and any immediate impacts downstream which could occur are attentuated by sedimentation in the impoundment. This results in protection for downstream river areas through the trapping of pollutants within the Ann Arbor reach of the river. However, the retention of these pollutants within the impoundment area raises the question of long term impacts due to the accumulation of materials in the park area.

The one exception to this general evaluation is the case of fecal coliform. Grab samples of the drains taken during this study, the 208 study, and other surveys have shown that fecal coliform levels in the range of 10^3 - 10^5 can be expected in the runoff waters. These discharges will result in fecal coliform levels above the standard for total body contact of 200 cfu/100 ml. established by the State of Michigan. The levels will be mixed in the large pond volume and with incoming water. Considering mixing coupled with natural die-off it can be estimated that the standard will be violated at various locations for 1-5 days after the storm depending on the size and duration of the event. Thus while water quality conditions in general are not severely degraded immediately during a storm event, water quality standards for total body contact can be expected to be exceeded at certain times, resulting in loss of potential recreational use of this area. The water quality standard for fecal coliform is not actually violated during the storm events due to the wording of the standard. The 200 cfu/100 ml limit is waived if the source of coliform is a non-point source.

As stated before, short term impacts of storm water discharge on this stretch of the Huron River did not appear to be severe for the monitored events. Long term impacts, however, require consideration due to the sedimentation of materials in the Geddes impoundment. The size of this impoundment in relationship to the river flow (54×10^6 Cu. Ft., median river flow - 300 cfs) results in a body of water with characteristics in between a river and a lake. In order to assess the impact of stormwater runoff under typical conditions, the data collected during this study was used to project drain discharge conditions and river conditions for various size rainfall events and on an annual loading basis.

The method utilized combined data on background water quality conditions in the river from STORET, river flow data from the USGS, and the event and annual non-point source loading data collected during this study. This data was utilized to project water quality conditions during storm events for various size storms and river flow conditions. River flows representing the median flow, mean flow, and dry flow (95% of flow values greater than), 300 cfs, 420 cfs, and 85 cfs respectively, were used in this evaluation. Rain event sizes of 0.3 inches (mean) and 0.9 inches (95% less than) were selected for the evaluation of projected concentrations in the river using the established event mean concentrations. Annual loadings, historical data above and below this reach of river, and the monitoring data presented earlier were used to project the quantity of pollutants being deposited in the sediments.

Evaluation of the projected annual loading data indicates that the long term impacts of the storm drain discharges to the river which are of most concern are the nutrient additions accelerating the eutrophication process and the accumulation of sediment in the pond which concentrates metals and destroys the benthic environment. Early studies on the river have shown that nutrient levels increase in the river as it flows towards Lake Erie. The section of river above the Geddes dam station receives virtually no point source discharges of consequence. Thus, increases in nutrients are attributable to non-point sources.

The data collected during this study indicates phosphorus is settled in the colder periods, while no net change in phosphorus was detected during the August survey. It is difficult to conclude that phosphorus is not settling in the summer time particularly given the additional data which shows that most of the phosphorus discharged is insoluble. Instead, it would appear that phosphorus is being utilized by the biological community, recycled from accumulated materials and is actually being discharged at higher levels than the incoming levels (Argo Dam) during dry periods. This would indicate that the phosphorus discharged by the drains enters the river, is utilized by biological community and is then discharged over a long period of time.

The phosphorus levels at Argo Dam ranged from 0.01 to 0.04 mg/l during current surveys and were in the range of 0.01 to 0.05 mg/l in previous studies. Phosphorus levels measured at Geddes Dam ranged from 0.01 to 0.10 mg/l during the current work and historical data over the past ten years shows a range 0.03-0.10 mg/l. This data shows a trend of generally increasing phosphorus levels. The increase in phosphorus can contribute to the development of eutrophic conditions which can result in a general degradation of water quality. Currently, moderate algal blooms have been noted in the impoundment but severe conditions have not apparently occurred. However, continued increases in phosphorus levels through continued discharge and increased discharge from new developed areas will undoubtedly have significant negative impacts on water quality conditions.

In addition to nutrients, large amounts of suspended solids are discharged from the storm drains (3,000,000 pounds annually). Heavy metals, particularly lead and iron, are associated with these solids materials and are deposited in the bottom of the pond. The data shows quite clearly that most of the solids discharged by the drains settle in the pond. In addition, data from Argo dam shows that very little settleable material enters the pond from upstream areas. The upstream ponds buffer Geddes Pond just as Geddes Pond buffers downstream areas. The buildup of silt in Geddes Pond is directly attributable to the storm drains in this reach.

It is quite apparent that the urban storm drains can have a major impact on water quality in the Geddes Pond reach of the Huron River. The 208 program identified this area of the Huron River as a segment being impacted by urban runoff and requiring further attention and ultimately control. The findings of this study support the 208 evaluation and indicate even more clearly the role of urban runoff in the area. Current general water quality conditions in the Geddes Pond reach could be classified as fair with no immediate severe water quality problems, but overall deterioration of water quality does occur as the river flows through the urban area. It can be expected that water quality in the river will deteriorate further if increasing loadings to the river continue. New development will result in increased loads to this stretch of river unless management controls are required. The current loads from urban runoff are generated from approximately 10,000 acres of highly developed land. There exists an additional 9,000 acres which can be developed in coming years and have direct discharge to Geddes Pond. This will undoubtedly result in deterioration of water quality and impairment of the recreational facilities which have been developed along the river.

This summary report has been based on the findings of the two year NURP project. The individual storm event data, detailed landuse information and other information is given a lengthy final report. All water quality data has been entered into the USEPA STORET system as utilized by the NURP headquarters team. The reader is referred to these resources for further information.

CHAPTER I. INTRODUCTION

BACKGROUND

General

This report presents the findings of a three year investigation of the quantity and quality of urban stormwater runoff with emphasis on the evaluation of various abatement alternatives. This project is part of the Nationwide Urban Runoff Program (NURP) undertaken by the United States Environmental Protection Agency. The study area, located in Washtenaw County, the City of Ann Arbor, Michigan, was selected based on the findings of the 208 program for the region, which targeted this area as an urban non-point source problem area, and based on the availability of in place Best Management Practices (BMP's). An overview of the 208 program in this region, the NURP program, and local involvement is presented for background on the project area.

The 208 Program

Section 208 of PL92-500, which is administered by the U.S. Environmental Protection Agency, - authorized and funded a planning process in most areas of the United States which was directed at evaluating the sources of water pollution and developing a management plan to correct and prevent water pollution. All sources of water pollution were considered - both point and non-point - and one conclusion from the overall effort was that urban non-point source runoff introduced a significant amount of pollutants to receiving waters. These pollutant loads from urban runoff are significant enough to alter the biological and chemical characteristics of the receiving water. In addition to such pollutants as suspended solids, biochemical oxygen demand, fecal coliform and nutrients, urban runoff is capable of delivering other, potentially more serious pollutants, as for example heavy metals and toxic organic compounds. The latter can be introduced to the food chain and biomagnify. The ultimate impact of the pollutants in urban runoff is to prevent the attainment of mandated water quality goals and the beneficial uses associated with such goals.

The Southeast Michigan Council of Governments (SEMCOG) was the designated 208 agency for this region. An Areawide Water Quality Management Plan was developed for the seven-county region of SEMCOG. This plan was based on the results of an intensive, two-year evaluation of all sources of water pollution. The SEMCOG 208 program included an extensive data gathering effort throughout the region. Several small watersheds were monitored; one of which was the Allen Drain Drainage District serving a portion of the City of Ann Arbor. This data provided region specific data regarding pollutant loads from various land uses and covers. A water quality survey of the Huron River also was performed which provided data on the conditions occurring in the Washtenaw County area. The SEMCOG study also included the development of a planning level model (SEM-STORM) which was used to handle the data for the numerous variables affecting urban runoff pollutant levels.

The SEMCOG 208 Management Plan called for additional monitoring and evaluation within three "problem areas"--the reach of the Huron River addressed in this study was the area of highest priority. Additionally, the water quality background paper prepared on the Huron River Basin concluded that the most significant cause of poor quality water in the Huron River in the Ann Arbor-Ypsilanti reach was point sources and urban stormwater runoff. In the reach being investigated - Argo Dam to Geddes Dam - there were no point sources while five major urban stormdrains discharged directly to the Huron River from the City of Ann Arbor. In this area, and downstream to the upper end of Ford Lake, ammonia and phosphorus concentrations and fecal coliform densities exceeded state standards. Coliform densities increased and exceeded guidelines especially after storm events in this reach.

Another background paper prepared by the SEMCOG 208 program investigated non-point sources in the region, and recommended an overall approach for managing pollution from urban non-point source runoff. The highlights were to:

a. prevent pollution from new development. This can be accomplished through on and off-site retention and detention techniques.

b. develop guidelines for the design and implementation of techniques for stormwater pollution abatement.

c. subject major regional development projects to a review of stormwater pollution abatement.

d. for existing, builtup urban areas, develop guidelines for local units of government's use. It is recognized that data on the cost-effectiveness of the measures to be considered does not presently exist, but that such data will be forthcoming from the Nationwide Urban Runoff Program.

e. undertake additional investigation and evaluation of stormwater pollution in Problem Areas. As mentioned above, this reach of the Huron River (Ann Arbor-Ypsilanti) is the Problem Area requiring first attention. The focus of the additional work recommended is to quantify the costs and effects of the various control measures.

The findings and recommendations of the SEMCOG 208 planning program have been used to define the program of work in this grant.

The Nationwide Urban Runoff Program

The magnitude of the impact of urban stormwater runoff calls for more attention than was previously given to this source of water pollution. Two areas requiring better definition are the cause and effect of pollution from urban runoff, and the cost-effectiveness of potential controls for urban stormwater runoff.

The Nationwide Urban Runoff Program (NURP) is being undertaken by the USEPA in connection with the 208 Program in order to assess the effectiveness and the cost of selected urban stormwater prevention and correction techniques. The intent is to investigate and evaluate a wide range of alternative techniques which are termed, by USEPA, Best Management Practices (BMP's). Evaluating BMP's nationwide was the policy option selected by the USEPA as the most prudent method of developing the body of information needed to correct and prevent pollution from urban stormwater runoff. The 208 Program resulted in the collection of much water quality data, but very little information exists, or has been collected by 208 heretofore, on the cost and effects of water pollution control techniques. The NURP will support the evaluation of selected BMP's throughout the country, and, based on such evaluations, determine which BMP's are cost-effective in a particular situation and at a given scale. This approach will yield data which is comparable within and between geographic regions. A collection of information will be available at the conclusion of NURP which will provide guidance to Federal, regional, State and local agencies responsible for implementing the Areawide Water Quality Management Plans.

Office of the Drain Commissioner

The Drain Commissioner is a county official elected at-large for a four year term who administers the Drain Code of Michigan, Public act 40 of 1956, as amended. The duties and responsibilities of the Drain Commissioner are quite broad. They include developing strategies for flood damage avoidance, establishing, designing, financing, constructing, operating, and maintaining stormwater drainage facilities and shaping policies concerning water and related land management. The Drain Commissioner is also responsible for preventing or abating pollution of the drains. In performing these duties the Commissioner's office becomes involved in acquiring rights-of-way, distributing assessments, and approving plans and specifications of drainage projects.

The Drain Commissioner can make a significant contribution to local water and land use policy. As a member of the county Public Works Board (under Public Act 185 of 1957, as amended) or as the Agent for the County Public Works Board (under Public Act 342 of 1939, as amended) the Drain Commissioner can influence water supply and sewage treatment programs for the county. Also, the Drain Commissioner is a member of the Subdivision Advisory Committee and his statutory authority to certify development plans as they affect drainage enables significant input on decisions relating to land development.

The Washtenaw County Drain Commissioner is not only interested in the impact of stormwater on Drains within his jurisdiction, but has the ability to implement both corrective and preventative measures to maintain water quality.

This project was the result of a grant to the Washtenaw County Drain Commissioner's office, through the 208 planning agency (SEMCOG), from the NURP program of the USEPA. The blending of the goals of the NURP program with the findings of the 208 study and the control of the Drain Commissioner over stormwater drainage systems presented a natural sponsoring team for this program. The objectives for the project were defined and the study performed within this framework.

OBJECTIVES

The primary objective of this study is to evaluate the effectiveness of Best Management Practices (BMP's) in reducing the pollutant loads present in urban stormwater runoff. Four specific BMP's have been selected for evaluation:

1. Surface Retention Basin
2. Surface Detention Basin
3. Natural Wetland
4. Runoff Ordinance

In order to meet this primary objective a series of tasks were undertaken to evaluate each BMP. These tasks included:

1. Determine the reduction in influent pollutant loads of various chemical constituents with a sampling and analysis program.

2. Determine capital and operating costs associated with the BMP's.

3. Identify factors affecting the performance of the BMP's.

4. Project the impact of BMP usage on water quality conditions.

In addition to the primary objective, other objectives of this study included estimation of the quantity and sources of urban runoff pollutants entering the Huron River in the study area, and assessment of the impact of these loads on water quality in the river with and without the use of BMP's. The accomplishments of these objectives was based on analyzing past studies in the Ann Arbor and surrounding areas, utilizing the inlet data from the BMP evaluations, collection of additional data on the river, determining the water quality in this reach of river as affected by the estimated loads, and evaluating the impact of the BMPs on water quality, particularly in terms of improved beneficial usages. This aspect of the study addresses the potential need for abatement procedures and the impact implementation of the BMP's would have on river water quality.

LITERATURE REVIEW

Huron River

Evaluations of the Huron River in the reach from Argo Dam to the outlet of Geddes Dam have involved either collection of original water quality data, or the use of existing data in numerical water quality simulation models. The preponderance of all existing data on this reach has been collected for limited objectives, over short periods of time, and largely during dry-weather conditions, or during wet-weather conditions only. Investigators have included university graduate students on semester-long field exercises, monthly routine State water quality sampling, Federal (FWPCA) surveys of limited episodes to characterize tributary pollution loads to western Lake Erie, a one-year survey of routine chemical parameters conducted twenty years ago, data from a single wet-weather event and from a dry-weather event collected by SEMCOG during the "208" water quality management planning program, joint USGS-County surface water sampling over an extensive network of stations using a limited basic parameter list to characterize the entire county's surface water resources, and private consultants carrying out evaluations for government agencies of the assimilation capacity in the reach to aid in sewage treatment plant design studies.

In reviewing the river data, one again must be mindful that in the reach being investigated approximately one-half of the distance between Argo Dam and Geddes Dam is the impoundment created by Geddes Dam. The remainder of the reach is a free-flowing stream. The primary inputs to the Huron River in this reach are the five urban stormdrain outlets which have been monitored during this evaluation. Because the river is impounded, the retention or residence time becomes an important consideration in assessing the impact of the stormwater runoff on the Huron River. None of the data existing before this evaluation was collected in the manner required to directly assist such an analysis, with the exception of the event monitored by the 208 agency.

Existing data does provide a sufficient profile of routine parameters, during dry-weather conditions for a twenty-year period of record. The existing reports of most value in making statements about this reach are those by Borchart 1958, and the U.S. Geological Survey, 1976. Table I-1 represents a composite summary of the major water quality characteristics and concentration ranges given by the reports mentioned above. In general, there has been no significant change in water quality in the reach over the period of record. With respect to nutrient loads, reported concentrations for both nitrogen and phosphorus tend to be higher than those considered necessary to stimulate algae blooms. The data suggests that a slight increase in BOD has occurred. The very limited data on metals does indicate concentrations which exceed standards or guidelines.

Storet data has been obtained from the Michigan Department of Natural Resources for two stations above Argo Dam and one station in Geddes Pond. Summarized data for the entire period of record at these stations will be presented in Chapter VI. A full listing of the entire statistical printout for all of the parameters sampled at these stations is presented in the separate data report.

TABLE I-1

Existing Chemical Quality of the Huron River Upstream from the Ann Arbor Wastewater Treatment Plant

Parameter	Concentration
pH	7.6 - 8.6
Dissolved Oxygen	80 - 120% saturated
Total Phosphorus (as P)	0.03 - 0.10 mg/l
Nitrate Nitrogen (as N)	0.03 - 0.40 mg/l
Nitrite Nitrogen (as N)	0.005 - 0.030 mg/l
Ammonia Nitrogen (as N)	0.15 - 0.50 mg/l
Organic Nitrogen (as N)	0.00 - 0.70 mg/l
Specific Conductance	560 - 700 micromhos

Reference: Environmental Assessment for Wastewater Management in the Ann Arbor - Ypsilanti Areas of the Huron Valley, Washtenaw County, Michigan. Environmental Control Technology Corporation, Ann Arbor, Michigan. 1976.

Storm Drain Discharges in the Ann Arbor Area

The storm drain discharges in the Ann Arbor area have been monitored periodically in recent years during both wet and dry weather periods(1-7). This data base is helpful in characterizing the general water quality of the drain discharges to the Huron River. Unfortunately, much of the early work was not comprehensive; key information on rainfall conditions, flow rates, time of sample collection, etc. is unavailable. However, these early works do provide data on specific parameters which when utilized with certain assumptions can be compared with current data. Of the five main storm drains discharging to Geddes Pond, Allen Drain has been studied the most extensively. This drain was monitored during the 208 program by the Southeast Michigan Council of Governments (SEMCOG)(6) and was utilized as one of the small watersheds for more intensive investigation. Other drains, Pittsfield-Ann Arbor, Swift Run, and Traver Creek, have eacn been monitored during recent years. A brief discussion of each of the water quality investigation reviewed is given below.

In 1963 and 1964 the Michigan Department of Health and the U.S. Department of Health, Education and Welfare, Public Health Service, studied water quality of Allen Drain as part of a survey to evaluate the pollutant loads associated with separate and combined sewer overflows(1). Primary emphasis of this study was to determine bacteriological contamination associated with urban runoff. Several storms were sampled and numerous analyses for total and fecal coliform, and fecal streptococcus were made. A few composite samples for nitrogen, phosphorus, and suspended solids were also collected. The main findings of this study were that high levels of fecal coliform (10^4 to 10^6 per 100 ml) were present in the runoff waters.

The University of Michigan, School of Public Health has conducted surveys of the Huron River and some of the storm drains during spring and summer periods. Sampling of the drains has generally been during dry weather; however, occasionally, a wet weather grab sample has been collected. Surveys during 1975, 1976, and 1977(2,3,4) included sample collection at Allen, Pittsfield-Ann Arbor, Swift Run and Traver Creek Drains. The general findings showed water quality conditions during dry weather flow to be reasonably good, while pollutant levels increased dramatically during increased flow periods due to rainfall.

A master thesis by Michael Winnell of the University of Michigan, School of Natural Resouces, details biological and chemical analyses performed on four Ann Arbor drains(5). This study was undertaken during 1973 through 1975 and was performed at request of the Parks and Recreation Department, City of Ann Arbor. Samples were collected at the mouth of the drain during high and low flow during each season of the year. A wide range of chemical parameters were monitored providing a good indication of general water quality conditions. Seasonal variations in several parameters are depicted and the increased pollutant loads during high flow periods is quite evident. Unfortunately, flow measurements and rainfall conditions are not discussed or presented in the report. Consequently, the data does not lend itself to detailed evaluation and assessment. However, the data is quite useful for comparison with SEMCOG data and it serves to indicate relative concentration levels of several pollutants.

The Southeast Michigan Council of Governments (SEMCOG) has intensively studied Allen Drain during 1976 and 1977 as part of the 208 planning effort authorized by PL-92-500 which is administered by the U.S. Environmental Protection Agency(6). SEMCOG has conducted several small watershed surveys specifically designed to obtain water quality data on storm drainage systems with various types of land use/cover. Four separate surveys during rain storms were conducted on the Allen Drain system. These results serve as the basis for the wet weather water quality evaluations for the 208 planning program. Several publications describing these surveys and water quality modeling activities undertaken by SEMCOG are available from the SEMCOG office in Detroit.

A study in 1978 for the Washtenaw County Drain Commissioner (7) focused on water quality conditions in the Allen, Swift Run, and Traver Creek drains. This study included the collection and evaluation of past information, presenting much of the data mentioned above, including water quality surveys to obtain water quality data during dry and wet weather periods, and including projection of pollutant loadings from various sub-districts within each drainage area. This study served as a basis for the development of this current study as it augmented the 208 findings published by SEMCOG.

INITIAL ASSUMPTIONS

Urban non-point source pollution was identified by the SEMCOG 208 Water Quality Management Plan as a major contributor to decreased water quality in the Huron River in the Ann Arbor area. The 208 program,in addition to other studies of urban runoff, also indicated that suspended material (suspended solids or sediment) was a major pollutant load in the runoff waters and that many other pollutants (e.g. phosphorus, organic chemicals, heavy metals) were associated with the suspended material. Therefore, these studies suggested that abatement procedures, i.e. Best Management Practices, which enhanced or provided for the sedimentation of the suspended material, could reduce the pollutant load in urban runoff and thus improve water quality conditions in the river.

Based on this background information the following assumptions were made in designing and implementing this study:

1. Urban runoff contains significant quantities of pollutants and that a major fraction of these pollutants are in the suspended form.

2. Best Management Practices which provided for the settling of suspended material would be effective in reducing pollutant loads.

3. Stormwater characteristics are highly variable and difficult to predict. However, the basic theory of sedimentation should apply, and thus, factors such as surface area, detention time, velocity, particle size, etc. should provide a basis for

evaluating removal mechanisms.

4. Retention/detention basins and wetlands provide the types of conditions which would allow sedimentation to occur and thus, would be appropriate Best Management Practices.

5. BMP's of this type, assuming they were effective, were practical for "real world" use in controlling urban runoff pollutants, particularly as they were currently being designed and constructed for flood control purposes.

6. Implementaton of BMP's would result in reduced pollutant loads to the receiving stream with subsequent improvement in water quality conditions.

REFERENCES

1. Michigan Department of Health, U.S. HEW, Public Health Service, "A Survey of Discharges from Combined Sewers and Separate Storm Sewers at Detroit and Ann Arbor, Michigan*, May 1963 through August 1964.

2. Gannon, et.al., "Survey of the Huron River - 1975," University of Michigan, School of Public Health, Dept. of Environmental and Industrial Health, 1976.

3. Gannan, et.al., "Survey of the Huron River - 1976," University of Michigan, School of Public Health, Dept. of Environmental and Industrial Health, 1976.

4. School of Public Health, University of Michigan, "A Brief Study of Selected Stormwater Drains in Ann Arbor, Michigan," Students in E & IH 570 Water Quality Management, School of Public Health, University of Michigan, December, 1977.

5. Winnell, Michael Hugh, "An Analysis of Water Quality of Four Tributaries of the Huron River in the Vicinity of Ann Arbor," 1975, Master Thesis, University of Michigan.

6. Data provided by Southeast Michigan Council of Governments, Detroit, Michigan, Small Watershed Surveys. Several reports describing surveys, and modeling, data available from Southeast Michigan Council of Governments.

7. E. Wayne Say and Associates, and Environmental Control Technology Corporation, "Allen Drain, Swift Run Drain and Traver Creek Drain - Report on Water Quality Conditions", Report to Washtenaw County Drain Commission, Feb., 1978.

CHAPTER II. STUDY AREA

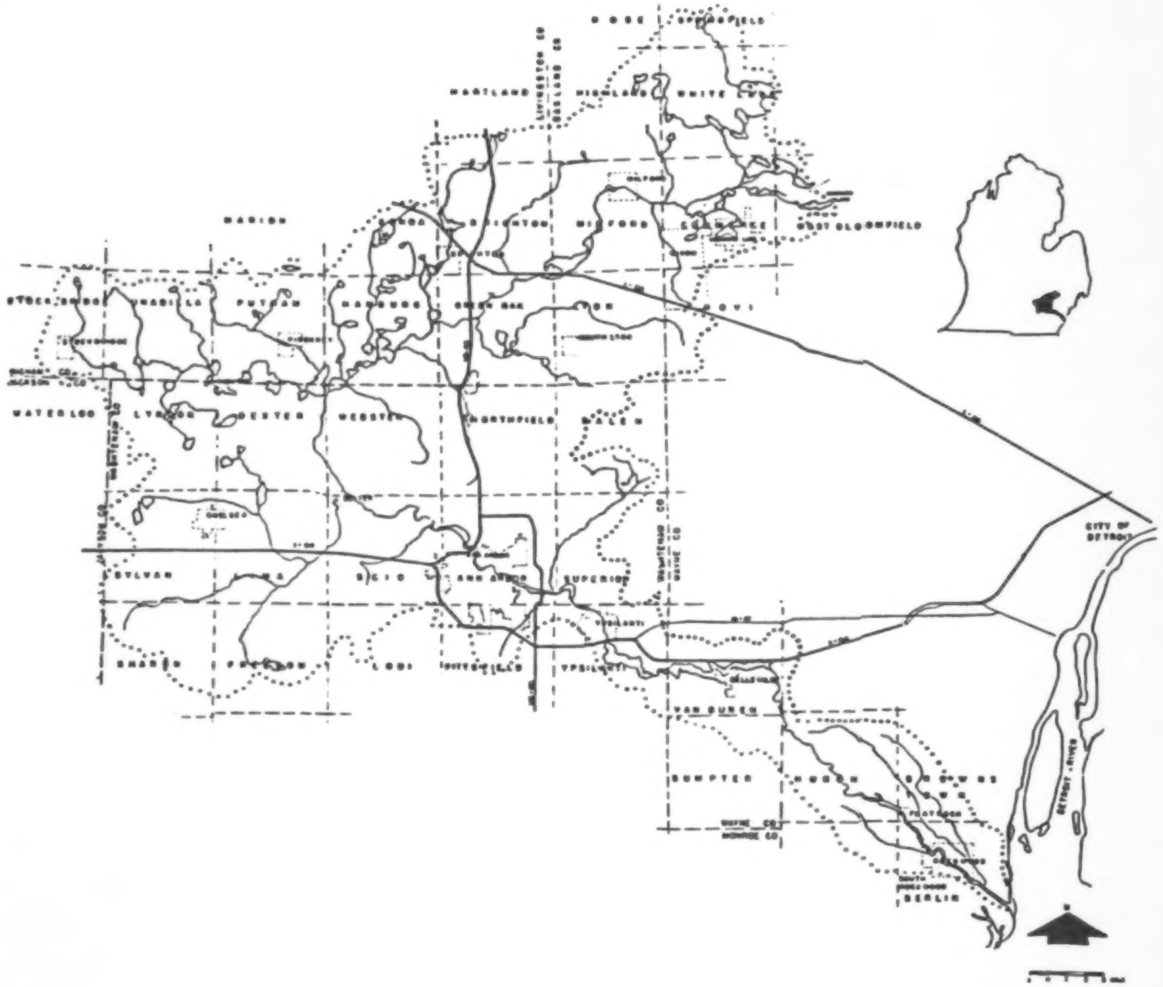
HURON RIVER BASIN

General

The Huron River Basin is located in Southeastern Michigan and discharges directly to Lake Erie. The basin encompasses approximately 2350 km^2 (908 mi^2) and includes portions of Ingham, Oakland, Livingston, Monroe, Washtenaw, and Wayne counties. Figure II-1 shows the drainage area of the river including major tributaries. A description of the river basin has been presented in the SEMCOG 208 study(1) of the river. The summary of the river basin, presented herein, is adopted from the 208 report.

Drainage

The Huron River begins at Big Lake in Oakland County and flows in a southerly direction. The river flows through a series of interconnected lakes and swampy areas with a poorly developed drainage system. The river turns to a southwesterly course near the town of Commerce and continues to flow through a series of lakes until it approaches Dexter. At this point, the river turns to a southeasterly direction and is free flowing as it approaches the Ann Arbor urban area. The river flows through a series of man-made impoundments and lakes as it passes through the main urban


ROSE
SPRINGFIELD
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OAKLAND CO.
HARTLAND
HIGHLAND
WHITE LAKE
MARION
MILFORD
WEST BLOOMFIELD
NOVI
STOCKBRIDGE
PUTNAM
WATERLOO
LYNDON
DEXTER
WEBSTER
NORTHFIELD
SALEM
WASHTENAW CO.
WAYNE CO.
CITY OF DETROIT
SYLVAN
SCIO
ANN ARBOR
SUPERIOR
SHARON
FREEDOM
LODI
PITTSFIELD
YPSILANTI
VAN BUREN
SUMPTER
WAYNE CO.
MONROE CO.
BERLIN
DETROIT RIVER

Figure II-1. Level I: Drainage Area Map, Huron River Basin, Ann Arbor, Michigan

area of Ann Arbor and Ypsilanti. Throughout its lower reach below these urban centers, the stream flows in a wide meandering belt with the channel generally cut into the supporting plain.

Two large lakes/impoundments are the significant feature of the river course just downstream of the Ann Arbor area. These two lakes, Ford and Belleville, were created by the installation of dams, originally to provide hydroelectric power in the area. The presence of these lakes result in a significant change in the river characteristics and require water quality impact investigations to consider this portion of river as interconnected lakes for analysis purposes rather than a free flowing river reach.

Major tributaries to the Huron River are North Creek, Pettibone Creek, Woodruff Creek, Davis Creek, South Ore Creek, Horseshoe Lake Outlet, Arms Creek, Portage River, Mill Creek, Honey Creek, Fleming Creek, and Silver Creek.

Numerous lakes in the upper reaches of the Huron River basin serves to attenuate peak flows by holding water in temporary storage. However, flooding still occurs and often causes problems. The lakes which serve to hold flood waters sometimes reach levels whereby lakeside development is affected. Washed shorelines, flooded cottages, innundated drain fields, and other flooding problems occur. Lakes in the Portage River basin and on the Huron River near Hamburg are particularly susceptible to flooding.

In the lower reaches of the Huron River flooding has also been a problem. At Ann Arbor flooding of the lowlands occurs during unusually heavy rains. Downstream, at Ypsilanti and Flat Rock, flooding presents a more serious problem. For example, the flood of April, 1947 caused an estimated 1.5 million dollars in damage at Ypsilanti. At Flat Rock that same flood was reported to have affected 70 percent of all homes and business places.

Topography

The land surface of the Huron River basin(2) ranges from mostly hilly or moderately undulating in the north and western parts to relatively flat terrain in the southeast. Interspersed in the north and western parts are local areas of relatively flat terrain. Elevations in the headwater areas, to the north and west, generally range between 275 meters (900 feet) and 335 meters (1,100 feet) above mean sea level but approach elevations of 365 meters (1,200 feet) in several places. Elevations are generally about 183 meters (600 feet) in the flatter lands to the southeast and at the mouth of the Huron River the elevation is 174 meters (572 feet) above sea level. Dividing the two topographically different areas are a series of ancient beaches which traverse the basin in a southwest to northeast direction. These beaches, formed by glacial lakes, are marked by a slight local increase of slope of the land surface.

Geology

The Huron River basin is underlain by two major types of earth materials -- consolidated bedrock and unconsolidated glacial deposits. The surface of the bedrock is encountered at depths ranging from about 15 meters (50 feet) to about 120 meters (400 feet). Overlying the bedrock are glacial drift and lake bed materials deposited during the Pleistocene period about one million years ago.

The bedrock formations that directly underlie the glacial deposits in the basin range in age from late Devonian in the eastern part to middle Mississippian in the western part. The formations dip generally west and northwest. The bedrock formations in the basin were traversed by several ice sheets during the glacial period. The great lobes of ice that covered the basin carved the bedrock surface, picked up and carried the rock debris, and later deposited the earth materials it had carried. These deposits form the basin's recognizable physiographical features.

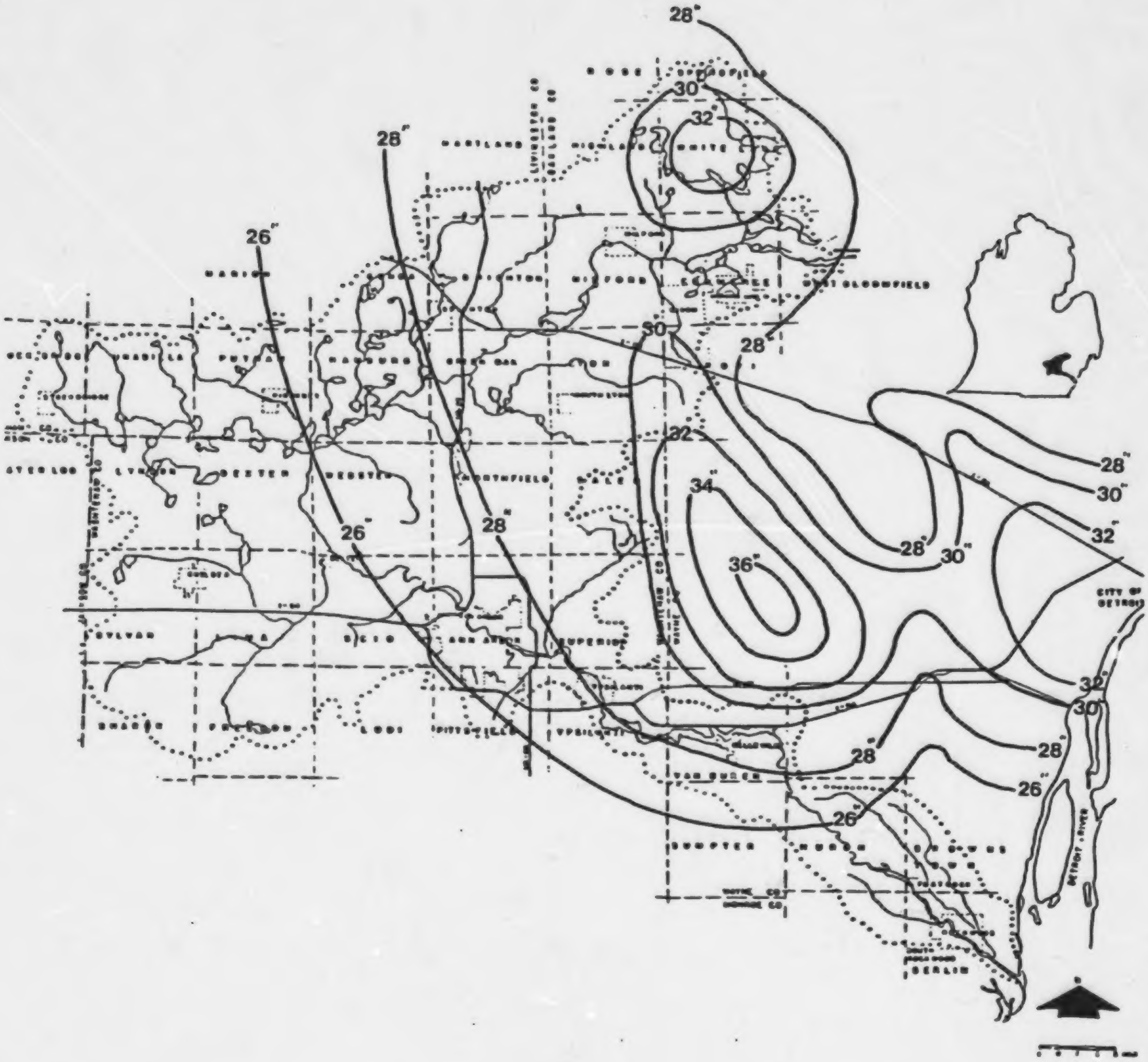
Deposits of the glacial period in the Huron River basin may be separated into two general areas. The western three quarters of the basin is composed of materials carried, shoved, and dumped by the glaciers as they advanced or retreated over the basin. This created both hilly, ridge-like terminal moraines and broad, level till plains. In addition to these morainal deposits, intensive meltwater flows deposited well-sorted sand and gravels, called outwash, and carried off the fine silts and clays. These glaciofluvial deposits also include gravel plains, outwash channels, kames and eskers.

In the eastern part of the basin below Ypsilanti, the flow of glacial meltwaters was greatly restricted and a series of large proglacial lakes inundated the area. Within these lakes, the fine sands, silts, and clays carried by glacial meltwaters were deposited. These lakebed deposits form the generally flat terrain throughout this part of the basin.

Climate

The southern Michigan area has a mean annual temperature of 49.4°F. Mean temperatures range from a high of 72.7°F in July to a low of 26.7°F in February. The growing season averages approximately 160 days. Mean monthly temperatures are generally above 32°F from March through November.

Precipitation patterns generally originate in the South and Southwest with rapid weather changes being quite common due to the mixing of tropical and polar air masses in the Great Lakes region. Annual rainfall in the Huron basin generally is in the range of 26 to 32 inches. Figures II-2 through 4 show the area rainfall summary for 1960-1973, and the years 1979 and 1980. As can be seen in these figures rainfall is rather uniform in the Huron basin. The Detroit-Dearborn area shown outside of the Huron Basin receives the largest amount of precipitation. The difference in precipitation is due to larger accumulations during the summer, when air-mass convective storms are common. These types of storms are typically intensified by the urban "heat island" effect. The Huron basin lies outside of the large urban area and receives a more uniform rainfall pattern.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DETROIT RIVER
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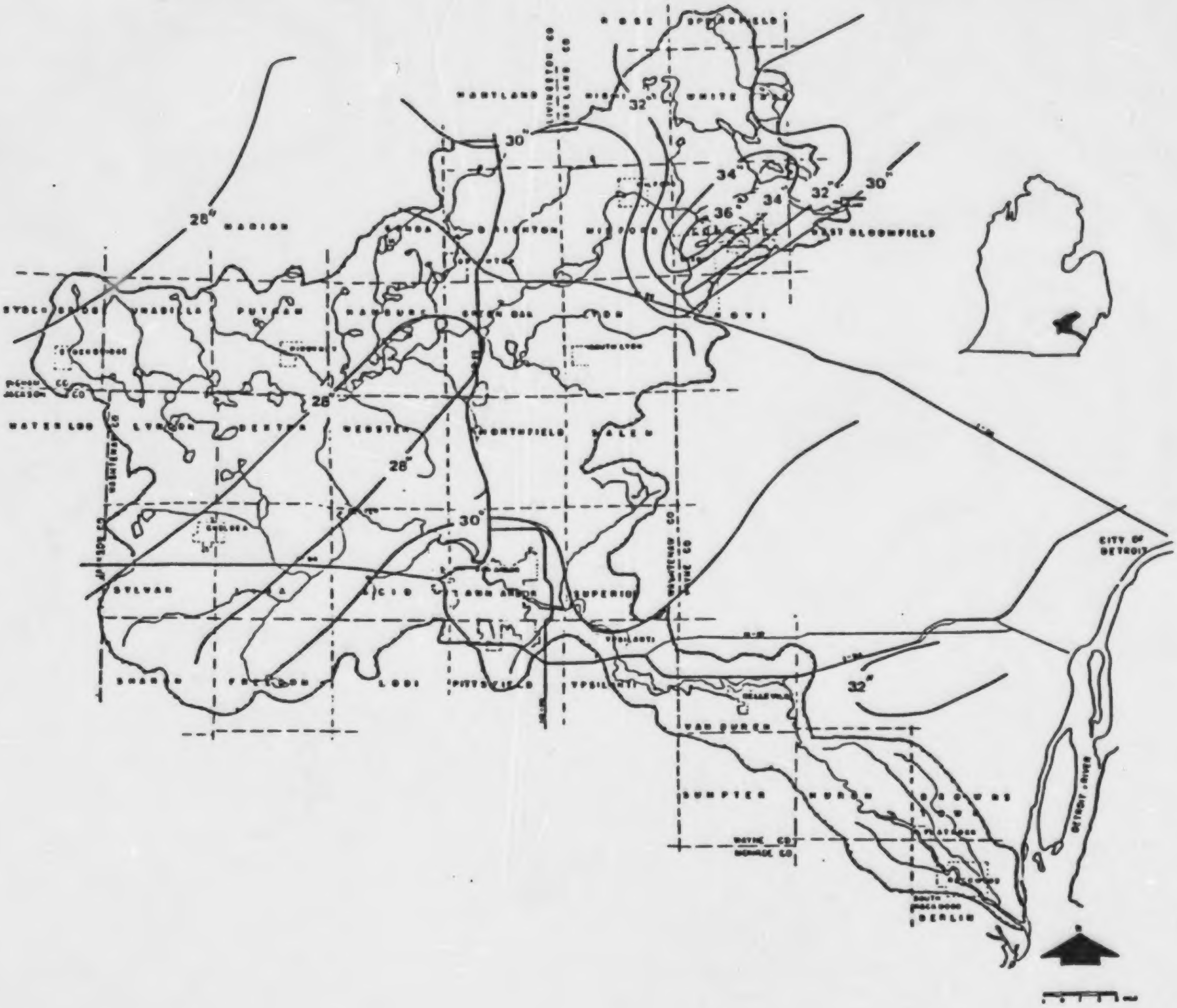
WAYNE CO
MONROE CO

Figure II-2. Level I: Area Rainfall Summary Map (1960-73)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BRIGHTON
MILFORD
COMMERCE
WEST BLOOMFIELD
STOCKBRIDGE
UNADILLA
PUTNAM
HAMBURG
GREEN OAK
LYON
NOVI
INGHAM CO
JACKSON CO
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CITY OF DETROIT
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PITTSFIELD
YPSILANTI
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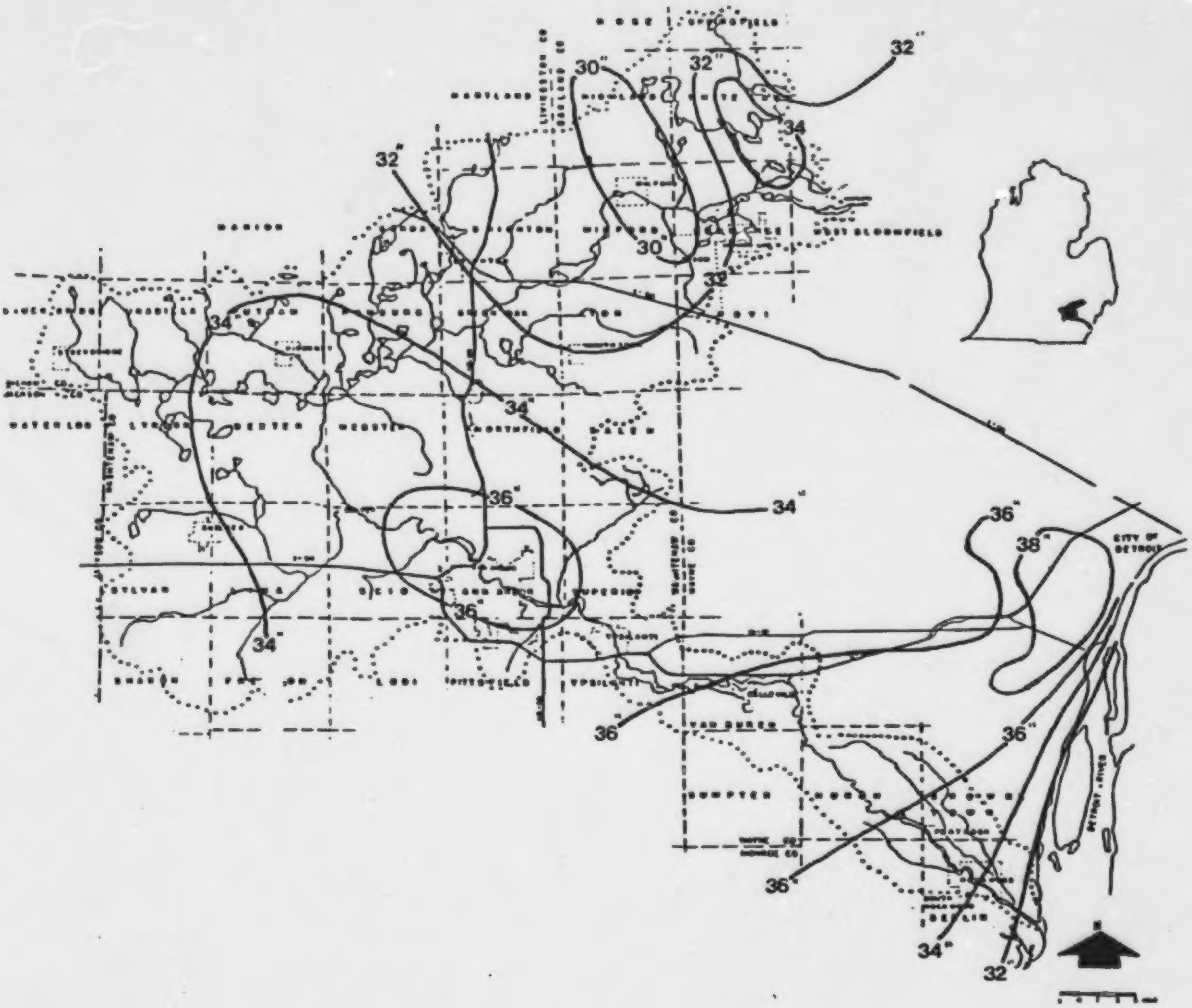
HURON
BROWNSTOWN
WAYNE CO
MONROE CO
DETROIT RIVER
BERLIN

Figure II-3. Level I: Area Rainfall Summary Map (1979)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CITY OF DETROIT
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Figure II-4. Level I: Area Rainfall Summary Map (1980)

The average annual rainfall for a 57 year period of record is 30.7 inches. Snowfall averages 37-38 inches per year. Significant snowfall generally begins in November and ends in March, although large single snowfall events have occurred in April. A detailed analysis of precipitation in the Ann Arbor study area, using the SYNOP program and a 30 year record is presented later in this chapter.

ANN ARBOR REACH - HURON RIVER

General

The section of the Huron River specifically being addressed in this study is the reach flowing through the City of Ann Arbor from Argo Dam to Geddes Dam. This reach of river is a mixture of free flowing water and a large impounded area created by Geddes Dam. Water entering this reach of river has passed through two impoundments (Barton and Argo Ponds) prior to entering the urban area. The river discharges from Argo Dam and flows freely for approximately 3 miles before entering the Geddes Pond impoundment. Geddes Pond is approximatley 5×10^7 cubic feet in volume and is a significant feature of the river in the urban area. The river exits the Ann Arbor area, flowing through two additional impoundment areas, and then enters two consecutive man-made lakes, Ford and Belleville. Table II-1 shows the physical properties of the various impoundments from just above Ann Arbor to Belleville Lake. These impoundments and lakes require careful consideration when

TABLE II-1

PHYSICAL PROPERTIES OF IMPOUNDMENTS
Huron River, Ann Arbor Michigan Area

Dam	Area of Pond (Acres)	Volume of Pond (Acre Ft.)	Length (Ft.)	Normal (Pond El.)	Drainage Area (Sq.Mi.)
French Landing (Belleville Lake	1,425	18,377	38,000	651.8	833
Ford (Ford Lake)	1,050	16,504	20.200	685.0	814
Peninsular Paper (Paper Mill Lake)	72	362	5,800	712.5	802
Superior (Superior Lake)	109	625	11,000	730.5	801
Geddes (Geddes Lake)	292	1,242	12,750	747.5	765
Argo (Argo Lake)	106	542	10,670	774.0	730
Barton (Barton Lake)	310	3,600	20.900	797.0	728
TOTALS	3,364	41,252	119,320		

analyzing flow and water quality information due to the large size. Geddes Pond, alone which is located in the reach under study, is large in comparison to the typical river flow (300 cfs) and thus results in a long time of passage for water flowing through the urban area. This body of water exhibits many of the water quality characteristics of small lakes, although it is flushed on a routine basis. This series of impoundments, just above, in, and below the Ann Arbor area result in the need to consider both river and small lake water quality parameters when describing impacts on the system. Detailed flow and water quality information for the Ann Arbor reach is presented in Chapter VI.

Drainage Systems - Ann Arbor Reach

The City of Ann Arbor is served by five major separate storm drains, all of which discharge stormwater runoff to the Huron River in the reach under study (Argo Dam to Geddes). The five drains, Allen, Traver Creek, Swift Run, Pittsfield-Ann Arbor, and North Campus are part of the study program with BMP's being located in three of these drainage systems. Figure II-5A shows the drainage boundaries in the urban area.

All storm drains in the area are designed to be physically separate from the sanitary lines. The extensive system of storm drains have been constructed during the past sixty years with both open channels and enclosed main drains being utilized. Main lines of the drains tend to follow the course of former natural streams. Storm drains in the City

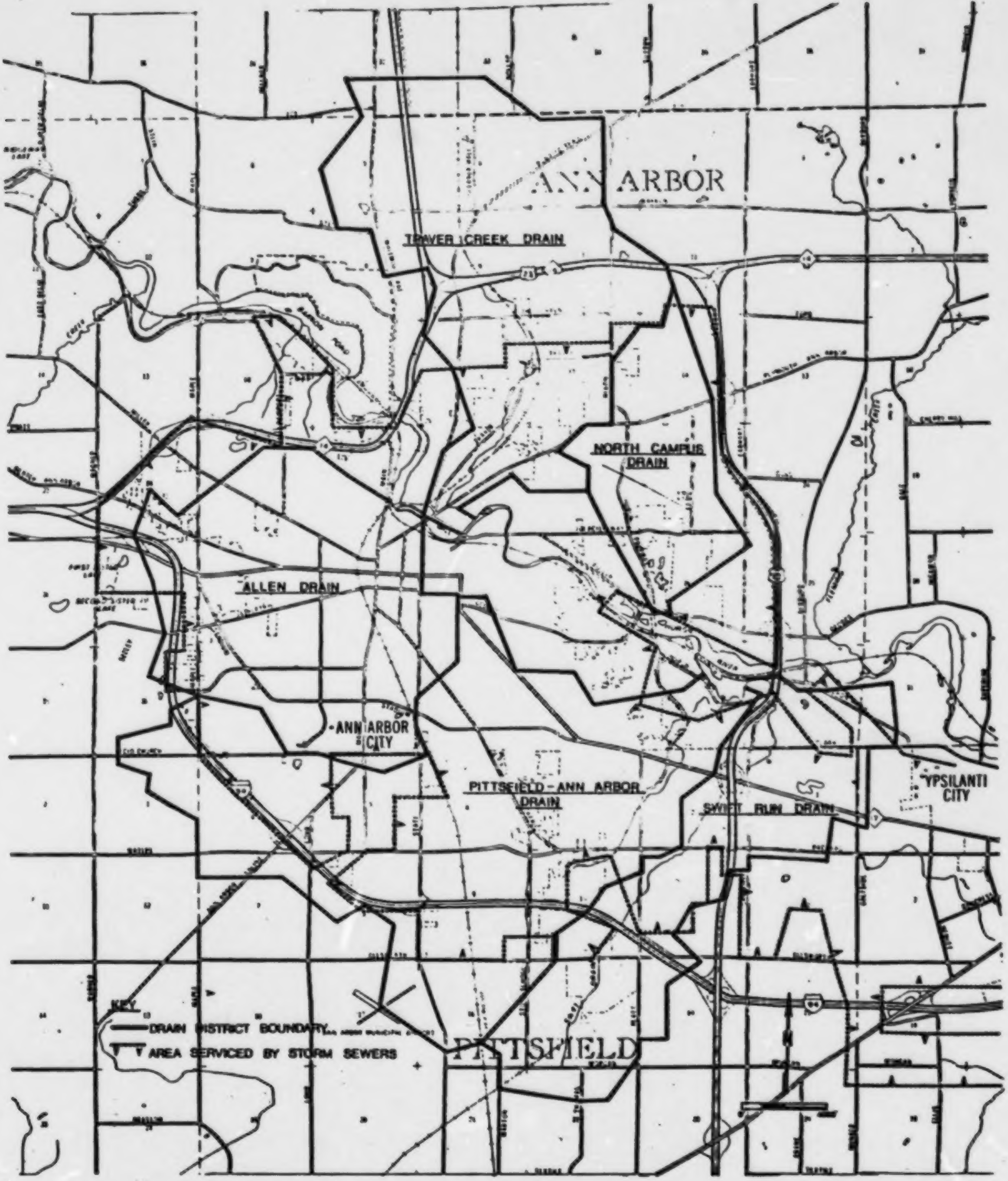
ANN ARBOR
TRAVER CREEK DRAIN
NORTH CAMPUS DRAIN
ALLEN DRAIN
ANN ARBOR CITY
PITTSFIELD-ANN ARBOR DRAIN
SWIFT RUN DRAIN
YPSILANTI CITY
PITTSFIELD
KEY
DRAIN DISTRICT BOUNDARY
AREA SERVICED BY STORM SEWERS

Figure II-5A. Level II: Drainage Boundaries in Urban Area

are the jurisdiction of either the City or the County Drain Commissioner. City owned drains are smaller drains which are lateral lines connecting to the main larger County controlled drains. The policy on roof gutters has changed over the years with older residential areas generally connected directly to the drainage system while newer areas are not directly connected to the system.

Each of the five drainage districts was monitored during this program and consequently specific descriptions of each drain were developed for the fixed site data base program for NURP. The additional physical detail on each drain is presented in later sections in this chapter.

Soils

The Soil Conservation Service has surveyed the soil types in the Ann Arbor area(3). Data from this survey was utilized to develop a soil profile for the urban area. Figure II-5 shows the four major hydrological soil groups in the area as defined by the NURP guidelines.

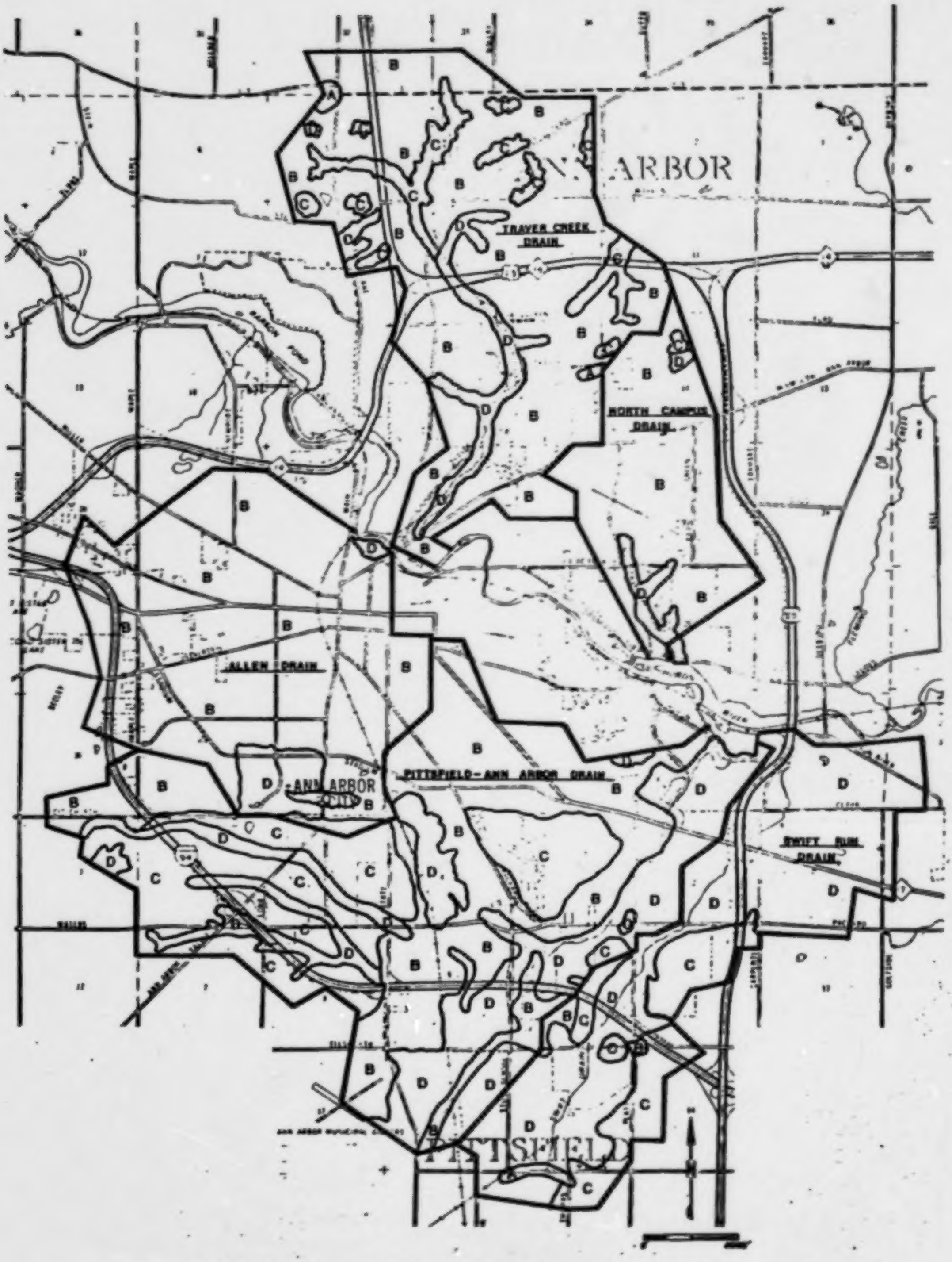
ANN ARBOR
TRAVER CREEK DRAIN
NORTH CAMPUS DRAIN
ALLEN DRAIN
PITTSFIELD-ANN ARBOR DRAIN
ANN ARBOR CITY
SWIFT RUN DRAIN
PITTSFIELD
B
C
D

Figure II-5. Level II: Soils Map of Ann Arbor, Michigan Study Area

HYDROLOGIC SOIL GROUPS

Hydrologic Group A -(low runoff potential). Soils that have high infiltration rates even when thoroughly wetted and a high rate of water transmission.

Hydrologic Group B -(moderately low runoff potential). Soils that have moderate infiltration rates when thoroughly wetted and a moderate rate of water transmission.

Hydrologic Group C -(moderately high runoff potential). Soils that have slow infiltration rates when thoroughly wetted and a slow rate of water transmission.

Hydrologic Group D -(high runoff potential). Soils that have slow infiltration rates when thoroughly wetted and a slow rate of water transmission.

Data Management Procedures Manual, Nationwide Urban Runoff Program, Environmental Protection Agency, March, 1980.

Land Use - Ann Arbor Area

Land use patterns in the Ann Arbor and surrounding area have been well defined and updated by the Washtenaw County Planning Department and by the 208 agency. Data from these agencies was utilized to prepare Level I and Level II land use maps as defined by the NURP program. Figure II-6 shows the Level I land use for the urban and surrounding area of the Huron River basin. Figures II-7 presents land use information for the Ann Arbor urban area at Level II detail.

The general land use in this portion of the Huron Basin is a combination of urban area and agriculture land. As shown in Figure II-6, a well defined urban corridor follows the river course. Ann Arbor was founded on the river banks, as is typical of many cities and has grown along the river and in a circular pattern out from the city center. The area outside of the city is dominated by agricultural land much of which is actively utilized. Only a limited amount of other land uses, i.e. forest or water exists in the area.

The urban area of Ann Arbor (Figure II-7) is primarily residential in character with a substantial amount of parkland spread throughout the city. There is very little heavy industry in the city. Commercial areas are located in the downstream area, in shopping malls, and along major arteries. The city has developed in this manner due to the strong influence of the University of Michigan. The major economic base in the city is in high technology research type companies and professional service organizations. Thus, overall the city is primarily a residential area with commercial areas to support the population of 110,000 and to provide office and laboratory type space.

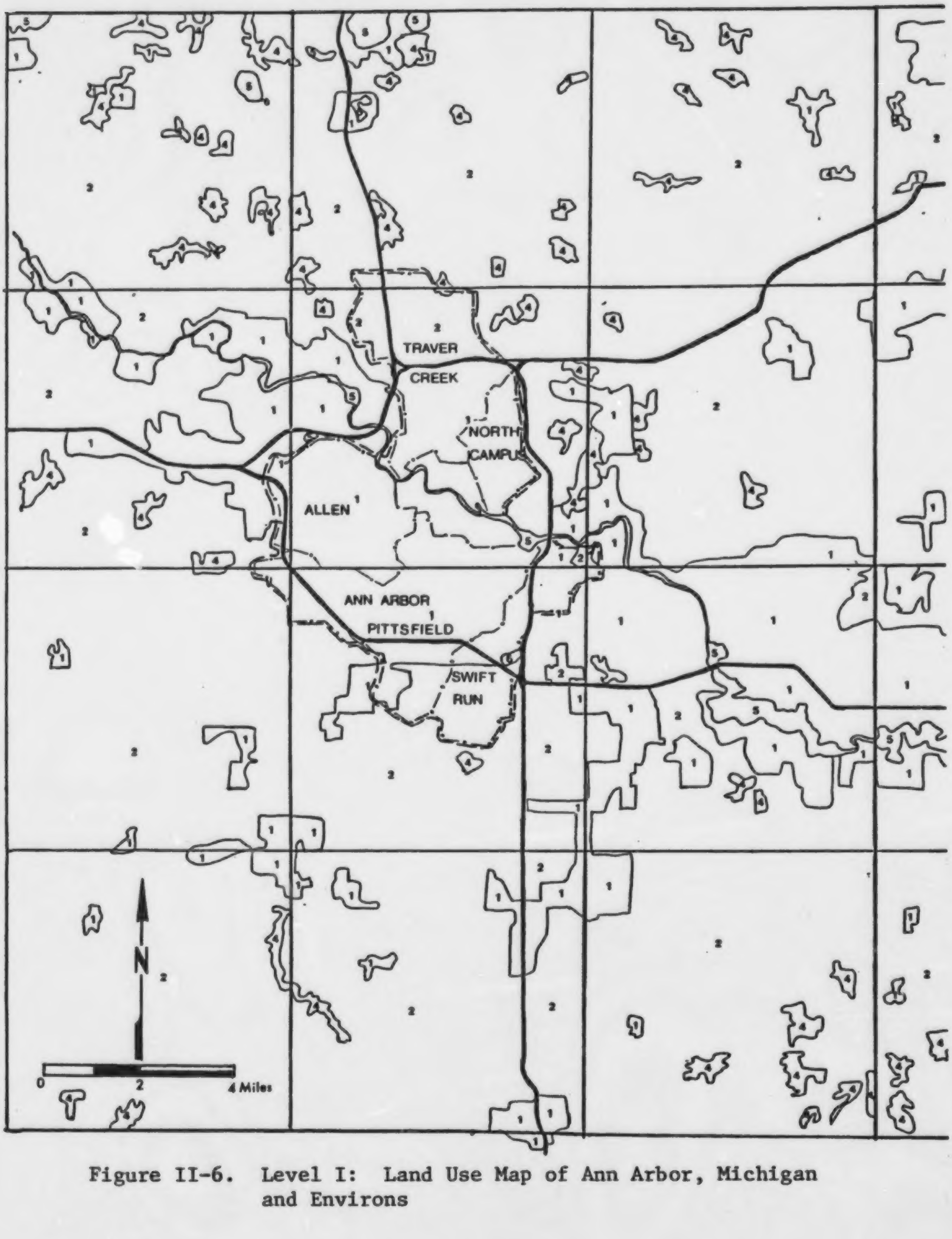
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Figure II-6. Level I: Land Use Map of Ann Arbor, Michigan and Environs

LAND USE DESIGNATIONS

LEVEL I	LEVEL II	LEVEL III
1. Urban	11. Residential	111. Rural and Pasture (F 1/2)*
		112. Low Density Residential (1/2-2)
		113. Medium Density Residental (3-8)
		114. High Density Residential (9+)
	12. Commercial	
	13. Industrial	
	14. Parkland	140. Parkland+
	15. Open Space	150. Idle or Vacant
	16. Other	160. Under Construction
2. Agriculture	20.	200.
3. Rangeland		
4. Forest		
5. Water	51. Streams/Canals	
	52. Lakes	
	53. Reservoirs	
	54. Bays/Estuaries	
	55. Oceans	
6. Wetlands		
7. Barren		
8. Other		

+ Parkland includes Institutional Land Uses (i.e. University of Michigan) as defined by NURP.

* Numbers in parentheses = number of dwelling units/acre.

Data Management Procedures Manual, Nationwide Urban Runoff Program, Environmental Protection Agency, March, 1980.

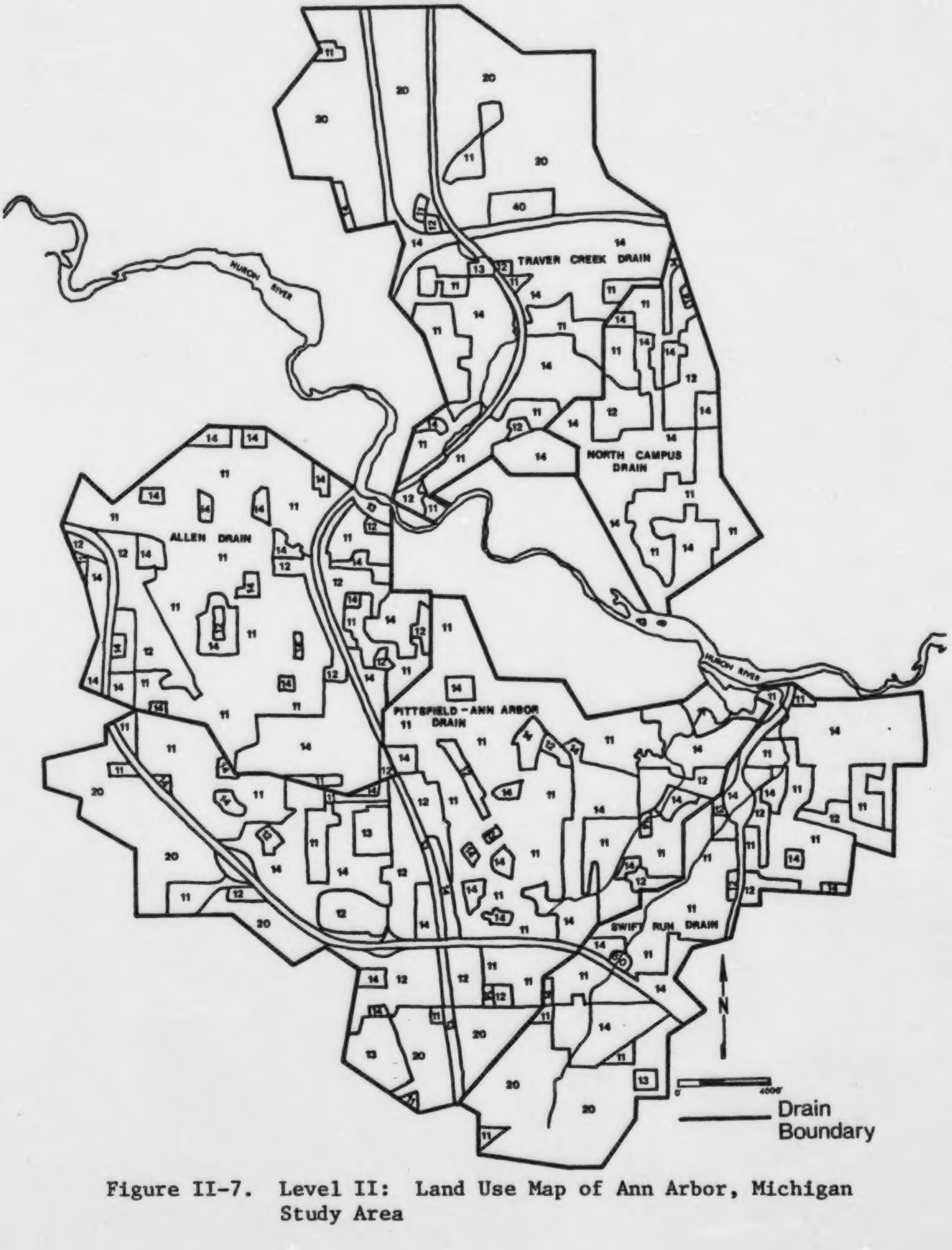

HURON RIVER
TRAVER CREEK DRAIN
NORTH CAMPUS DRAIN
ALLEN DRAIN
PITTSFIELD - ANN ARBOR DRAIN
SWIFT RUN DRAIN
HURON RIVER
N
0
4000'
Drain Boundary

Figure II-7. Level II: Land Use Map of Ann Arbor, Michigan Study Area

Specific Landuse and Drainage Area Characteristics

General

An extensive data gathering effort to define the physical conditions in each drainage district or sub-drainage district monitored during this study was undertaken in accordance with the NURP program guidelines. A set of fixed site data was developed for each drainage area and this information has been computerized by the NURP project team. The fixed site data base includes the following types of information:

Catchment area
Catchment population
Catchment slope
Drain channel slope
Length of channel

Separate sewer area with curb and gutter or swales/ditches

Lane miles
Road types and conditions
Landfill areas
Eroding stream banks lenghts

Landuse (Level III detail)
Impervious area by land use

Hydrological soil group
Pervious area by soil group
Water capacity

Permeability
Erodibility
pH

A full listing of this information by catchment is presented in the separate data report prepared for this project. The following sections provide a brief description of each district and presents a summary of the land use data and catchment characteristics.

Pittsfield-Ann Arbor Drain Drainage District

This 6363 acre district lies between the Allen Creek District to its West and the Swift Run District to its East (Figure II-5A). The flow of the main line of the Drain is toward the north to its confluence with the Huron River in the so-called "South Pond" of Geddes Pond. A major stormwater drainage improvement project was completed on the Drain in 1979 which consisted of straightening, deepening, widening, building two on-line retention basins, and enclosing certain lengths of the Drain. Approximately 9.5 miles of Interstate 94 traverses the district and contributes runoff.

One of the BMP's is located in this district. This retention basin receives runoff from two large sub-districts, one to the north and one to the south and west. Each of these districts was monitored separately during the study. A third sub-district included the remaining drainage area below the retention basin. Figure II-8 shows the land use in the total drainage area and Table II-2 provides a summary of these land uses.

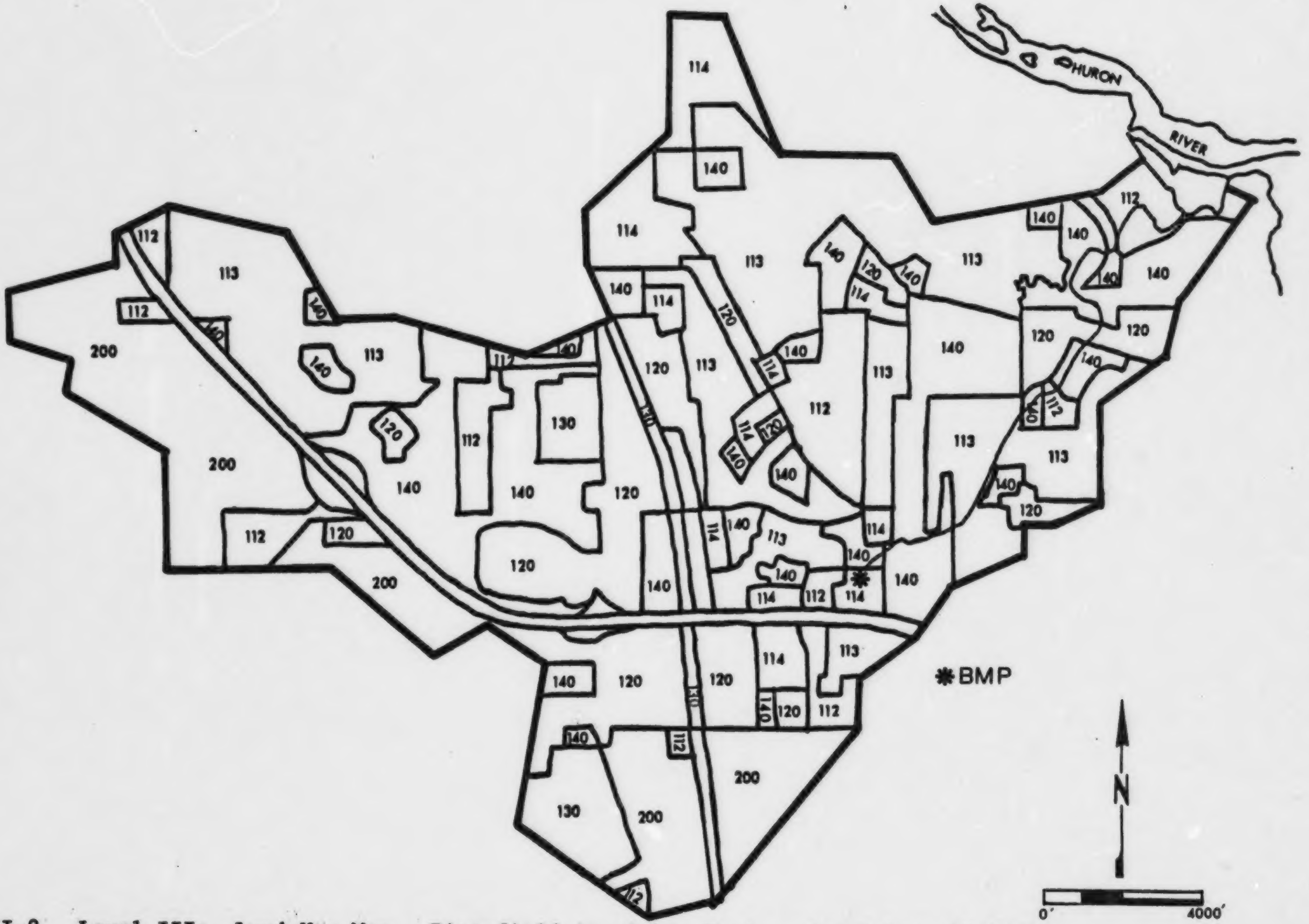

HURON
RIVER
BMP
N
0'
4000'

Figure II-8. Level III: Land Use Map - Pittsfield Ann Arbor Drain - Ann Arbor, Michigan

TABLE II-2

LAND USE SUMMARY
Pittsfield - Ann Arbor Drain

	North Inlet Acres	South Inlet Acres	Total District Acres
Rural and Pasture	11	345	356
Low Density Residential	241	117	483
Med. Density Residential	938	62	1,714
High Density Residential	378	92	510
Commercial	293	457	861
Industrial	80	138	218
Parkland	618	485	1,604
Agricultural	312	305	617
Total	2,871	2,001	6,363
Percent Impervious	26	21	22
Population	18,800	3,800	27,700
Catchment Average Slope (ft./mile)	60.7	33.8	61.6
Channel Slope (ft./mile)	10.6	17.6	15.4
Channel Length (ft.)	10,200	10,000	33.900

The first sub-district (south) is approximatley 31% of the total area and is the Western and Southern portion of the district. In this area is located a regional shopping center, a local airport, and industrial and research park, and much land devoted to "open" uses, i.e., farming, woodlots, and vacant. The watercourse providing drainage is open, but has been greatly channelized. There are five "wet" on-line retention ponds on the shopping center site, and another on-line "wet" retention pond on the drain downstream of the research park and airport, as well as being downstream of the shopping center. This sub-district contains the highest proportion of open space and the least percentage of impervious area. This area has been labeled "South Arm" on several of the Tables.

The second sub-drainage area is the largest one, accounting for approximately 46% of the total area. This area lies in the northern section of the District and the flow from it is southerly. The drain is entirely enclosed. This sub-district is characterized by having older and more developed urban land covers than either of the other two sub-districts. Land uses include a major university, medium and high density residences, and some strip commercial. The northern watercourse entering the retention area is also one of the water quality monitoring station sites. This sub-district has a level of imperviousness intermediate between the other two sub-districts.

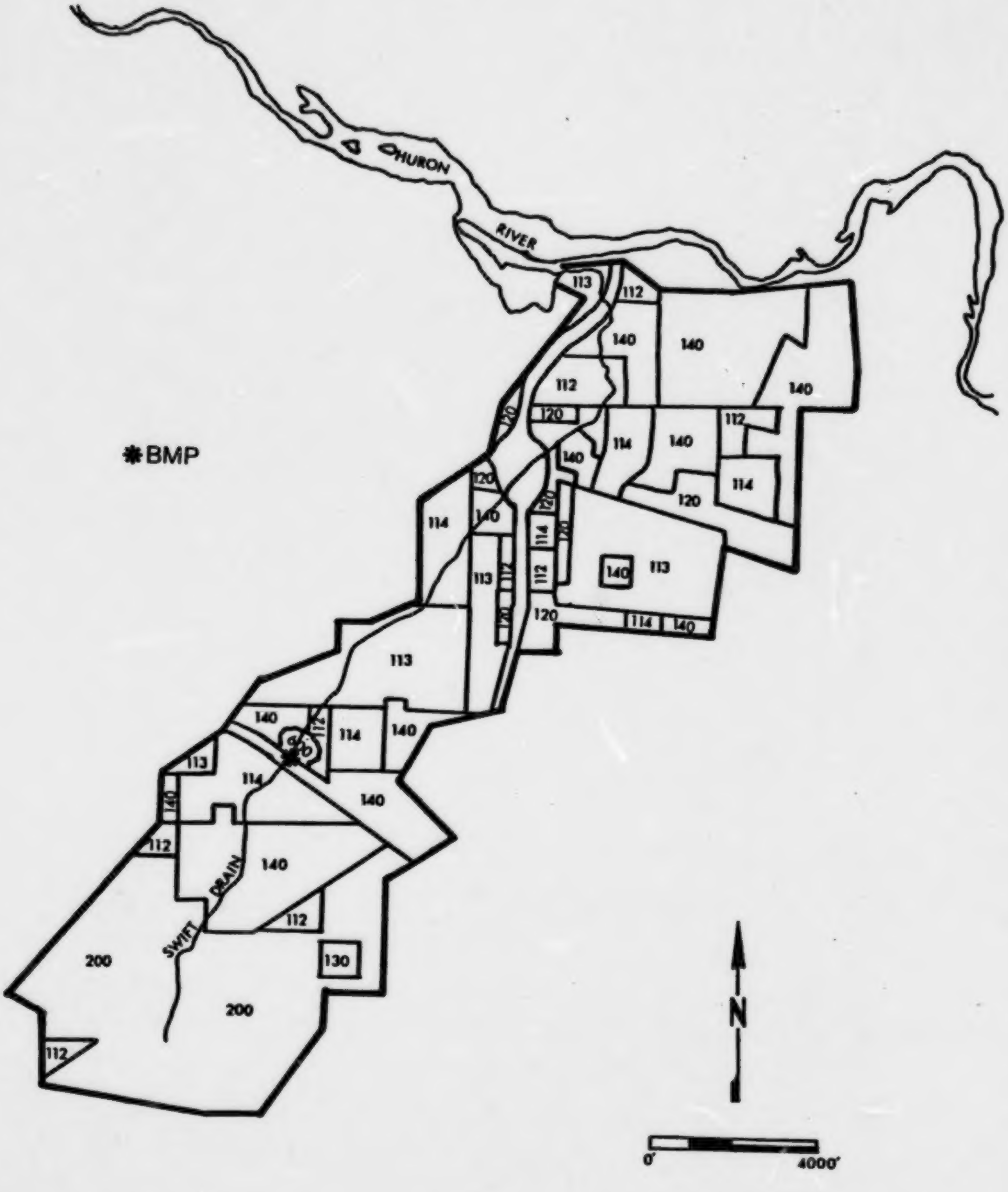
The last sub-district covers the area from the outlet of the retention area being monitored to the confluence of Drain with the Huron River. While this sub-district is the smallest, it contains the greatest percent of impervious area. Land uses are primarily residential and commercial.

Swift Run Drainage District

The watershed is approximately 2826 acres. The drainage area above the wetland is approximatley 917 acres. Swift Run is a tributary to the Huron River at Geddes Pond. The stream flows northeasterly from its origin in Section 15 of Pittsfield Township and is open throughout most of its course.

Land use in the upper portion of the district are open and agricultural in nature. The impact of urbanization begins with the City of Ann Arbor's 110 acre landfill located adjacent to the Drain immediately south of Ellsworth Road. North of Ellsworth Road dwellings in the Eastern portion of the University Townshouse site have basements at elevations below the ditch bottom elevations.

The wetland has been acquired by the Office of the Drain Commissioner in order to incorporate storage and water quality improvement into the design of the project. From this point to the outlet of the drain at the Huron River the drainage district has been almost completely developed with urban, residential uses. Commercial strips also occur south of the wetland. The impervious surface increases and the roads are paved with curb and gutter drainage (but no catch basins with sumps).


HURON
RIVER
BMP
SWIFT DRAIN
113
112
140
140
112
140
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120
114
114
140
120
114
120
113
112
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120
114
140
113
140
112
114
140
113
114
140
140
112
140
112
200
130
200
112
N
0'
4000'

Figure II-9. Level III: Land Use Map - Swift Run Drain, Ann Arbor, Michigan

TABLE II-3

LAND USE SUMMARY
Swift Run Drain

	Wetland Inlet (Acres)	Total District (Acres)
Rural and Pasture	509	509
Low Density Residential	30	151
Med. Density Residential	13	574
High Density Residential	90	319
Commercial	4	123
Industrial	14	14
Parkland	187	1,005
Agricultural	360	360
Wetlands	0	20
Total	1,207	3,075
Percent Impervious	3	14
Population	2,700	10,800
Catchment Average Slope (ft./mile)	32.1	39.6
Channel Slope (ft./mile)	6.9	17.8
Channel Length (ft.)	8,000	24,000

Traver Creek Drainage District

The Traver Creek Drainage District (1,514 acres) comprises the portion of the Traver Creek watershed within the City of Ann Arbor. The watershed is approximately 4,566 acres and includes land in Ann Arbor Township and Northfield Township. The city limits extend to M-14 which forms a dividing line between urban land use and land cover to the south, and rural, agricultural land use and land cover to the north in Ann Arbor Township. The watershed is funnel-shaped with the discharge passing through a very narrow mouth to the Huron River. The watercourse flows continuously throughout the year although the very flat grade of the streambed north of M-14 coupled with the pervious, agricultural cover produces a stream of low velocity and with rooted vegetation growing up to the water's edge. Excepting road culverts, the stream is totally open.

The retention basin BMP in this district lies just south of M-14. A single inlet from the upstream catchment area directs the flow to the basin. Figure II-10 and Table II-4 show the land uses above and below the retention area.

South of M-14 the grade of the streambed increases greatly especially from the Leslie Park Golf Course to Broadway Road. In this reach, the stream is relatively more swift with little vegetation along the banks, steeper banks, and a more firm or rock bed. Urban land uses along the Drain corridor south of Traver Road are constant and represent incursions on the flood plain. Open space is

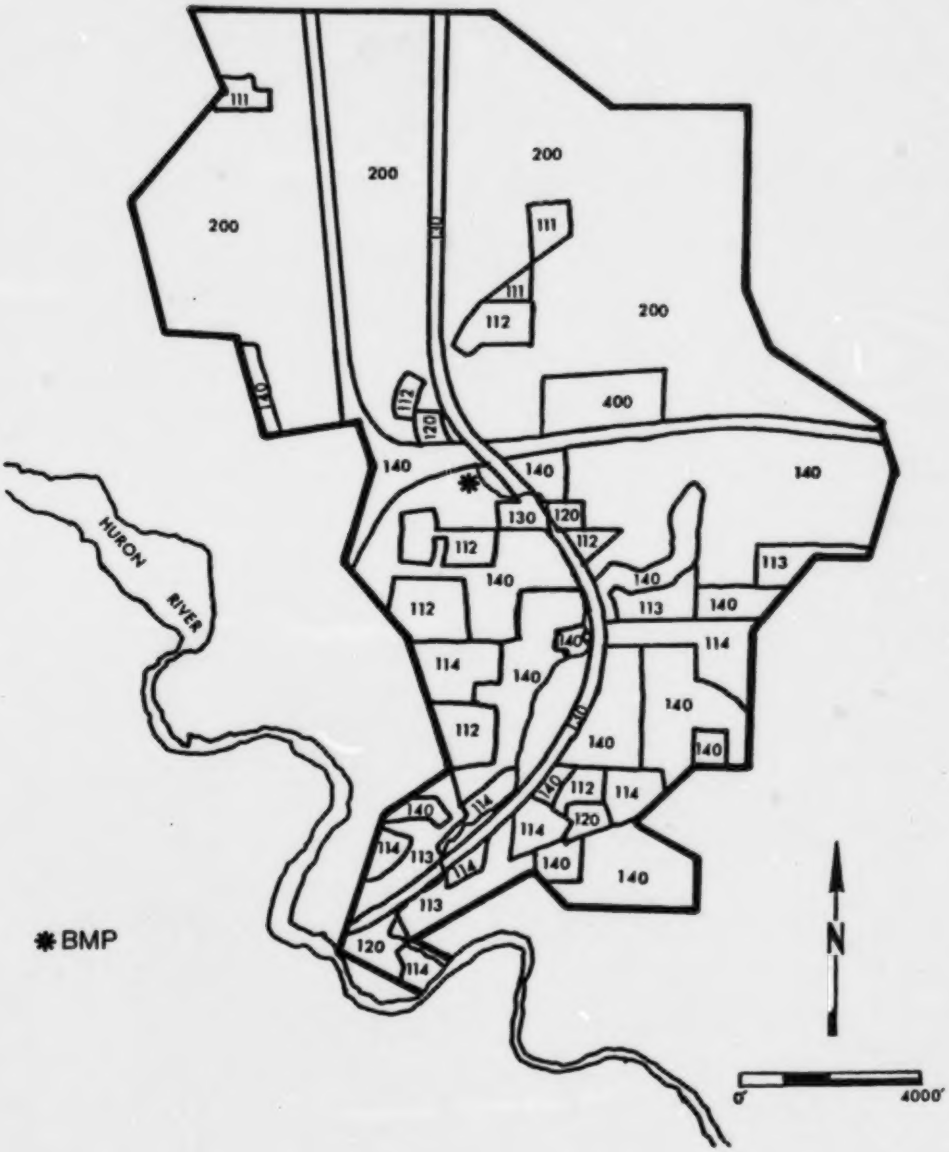

111
200
200
200
111
111
112
200
140
112
120
400
140
140
140
HURON
RIVER
130
120
112
112
140
113
140
112
113
140
140
114
114
140
112
140
140
140
140
112
114
114
140
114
120
114
113
114
140
140
113
120
114
BMP
N
0'
4000'

Figure II-10. Level III: Land Use Map - Traver Creek Drain, Ann Arbor, Michigan

TABLE II-4

LAND USE SUMMARY
Traver Creek Drain

	Retention Basin Inlet (Acres)	Total District (Acres)
Rural and Pasture	125	125
Low Density Residential	52	161
Med. Density Residential	0	174
High Density Residential	0	192
Commercial	10	49
Industrial	37	96
Parkland	4	1,530
Agricultural	1,862	1,862
Forest	213	213
Total	2,303	4,402
Percent Impervious	6	9
Population	160	8,400
Catchment Average Slope (ft./mile)	33.2	68.6
Channel Slope (ft./mile)	28.5	37.8
Channel Length (ft.)	9,500	25,700

found only in Plymouth Park. Five major apartment complexes have been constructed immediately adjacent to the stream, and only one, Traver Knoll II, was sited based on an analysis of the flood plain elevations. The stream was, however, relocated through Traver Knoll II, and the slope of the banks (3:1) along with the slope of the streambed have increased the solids load which is scoured and carried away during wet-weather conditions.

The shape of the watershed, slope of the streambed, and development from Traver Road to the mouth, has produced conditions which result in flooding. Flood threats are most serious between Broadway and the Huron River, which coincides with the greatest concentration of dwelling units in the watershed.

Flooding damage experienced in the City in 1968 occurred primarily along the tributaries to the Huron, and damage along Traver Creek was among the highest sustained anywhere in the City.

Allen Creek Drain Drainage District

The drainage district for Allen Creek Drain is approximately 3800 acres lying south of and tributary to the Huron River. The District is identical to the watershed of the Drain, and the majority of the District lies within the City of Ann Arbor. Much of the early commercial and residential development within the City occurred within the Allen Creek watershed, and, in fact, along Allen Creek. Figure II-11 and Table II-5 show the land uses for this district. Approximately 70% of the District lies to the west of the main stem of the Drain, and this area is divided into four major sub-districts each served by a totally enclosed storm drainage network physically separate from the sanitary sewer system. In all parts of the district the roads are paved and have curb and gutters. Residential, commercial, and some industrial uses are found within the District, and each use is clustered into homogeneous areas. At this time there are three industrial dischargers to the Drain which are required to have an NPDES Permit, but each permit regulates non-contact cooling water discharges. The older core of the city contains the commercial land uses and some of the industrial land uses. The outlying areas contain the residential use with neighborhoods ranging in age from 75 years to 10 to 20 years. The commercial core lies east of the main stem, and the balance of the District east of the main stem is dominated by the University of Michigan.

Major surface transportation corridors traverse the district running east-west and north-south. Much of the commercial core is impervious surface of some kind--rooftop, parking lots and sidewalks. The Ann Arbor railroad tracks closely parallel the main stem of the drain.

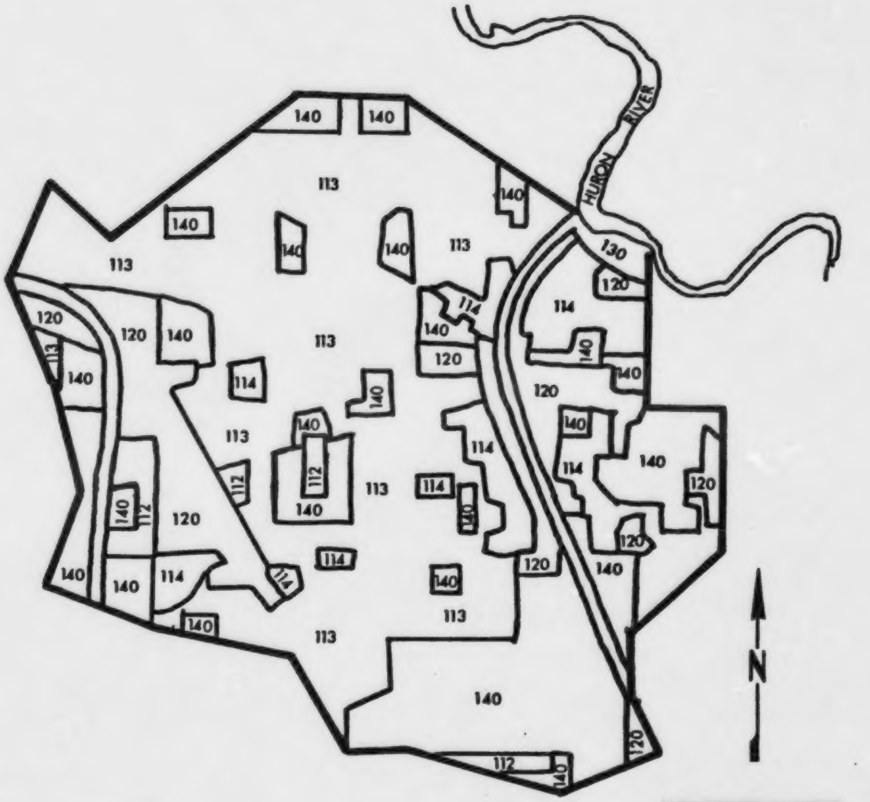

HURON RIVER
113
114
112
120
130
140
N
0'
4000'

Figure II-11. Level III: Land Use Map - Allen Creek Drain, Ann Arbor, Michigan

TABLE II-5

LAND USE SUMMARY
Allen and North Campus Drains

	Allen Drain (Acres)	North Campus Drain (Acres)
Rural and Pasture	000	000
Low Density Residential	139	255
Med. Density Residential	1,682	395
High Density Residential	390	61
Commericial	344	250
Industrial	65	000
Parkland	1,180	580
Total	3,800	1,541
Percent Impervious	34	19
Population	35,700	2,800
Catchment Average Slope (ft./Mile)	82.0	89.8
Channel Slope (ft./mile)	57.9	53.3
Channel Length (ft.)	11,200	15,500

Development throughout the district has encroached on the flood plain of the main stem and along or over all major branches. Except for a few hundred feet along the Murray-Washington Branch, the main stem and all four branches are totally enclosed and below grade. The enclosure of the main stem occurred in 1925, and it has not been modified since then although substantial development has occurred within the district since the 1920's. Structurally the drain appears to be sound, but has been damaged by wear and/or discharges at a few locations. Sediment deposits within the larger reaches have been located during inspections. The four branches (Eberwhite, Murray-Washington, West Park-South, West Park-North) lie west of the main stem of the drain and join the main stem within approximately 1100 feet of each other. The time required to concentrate peak flows in the main drain with such a configuration is veryshort, and the land along the lower half of the drain is likely to be inundated more frequently, at a higher stage and with more damage sustained. The drain outlets to the Huron River 100 feet downstream of Argo Dam.

The design of the stormdrain system reflects the traditional assumptions followed in urban stormwater drainage: increase of the hydraulic efficiency with steep slopes, use large diameter enclosed tile to convey the "ten-year" storm, use paved curb and gutters to maximize the removal of stormwater from road surfaces, collect and discharge overland runoff from impervious surfaces in as short a time as possible, and flush all solids or suspended material through the enclosed tile system without sumps in the catch basins.

The connection of roof gutters and downspouts to the stormdrain has been required or encouraged at various times in the City's history. An informal inspection of different neighborhoods in the district revealed many downspouts pointed at driveways or sidewalks.

Stormdrains also enter the main stem of the drain from the east within the City of Ann Arbor. While these drains are connected to the main drain which is the responsibility of the Drainage District, they were built and maintained by the City of Ann Arbor. The area served by these drains contains the commercial and office uses of the district, much of the streets related to commercial use, as well as the main campus of the University of Michigan.

North Campus Drain Drainage District

This is a district of 1571 acres lying north of the Huron River and Southeast of the Traver Creek Drainage District. Runoff flows through a natural, open watercourse in a southerly direction to join the Huron in the Geddes Pond area approximately 300 feet east of the Huron Parkway. Low-density residential development exists in the extreme northern tip of the district and in a new subdivision lying on the eastern boundary. Medium and high density student housing on the University's North Campus occurs in the northern portion of the District. Much of the District is open, rolling land with woodlots. Occasionally steep slopes occur at the end of ground morraines and eskers. One small section of commercial use is concentrated in the northern portion of the District. Figure II-12 and Table II-5 show land uses for this district.

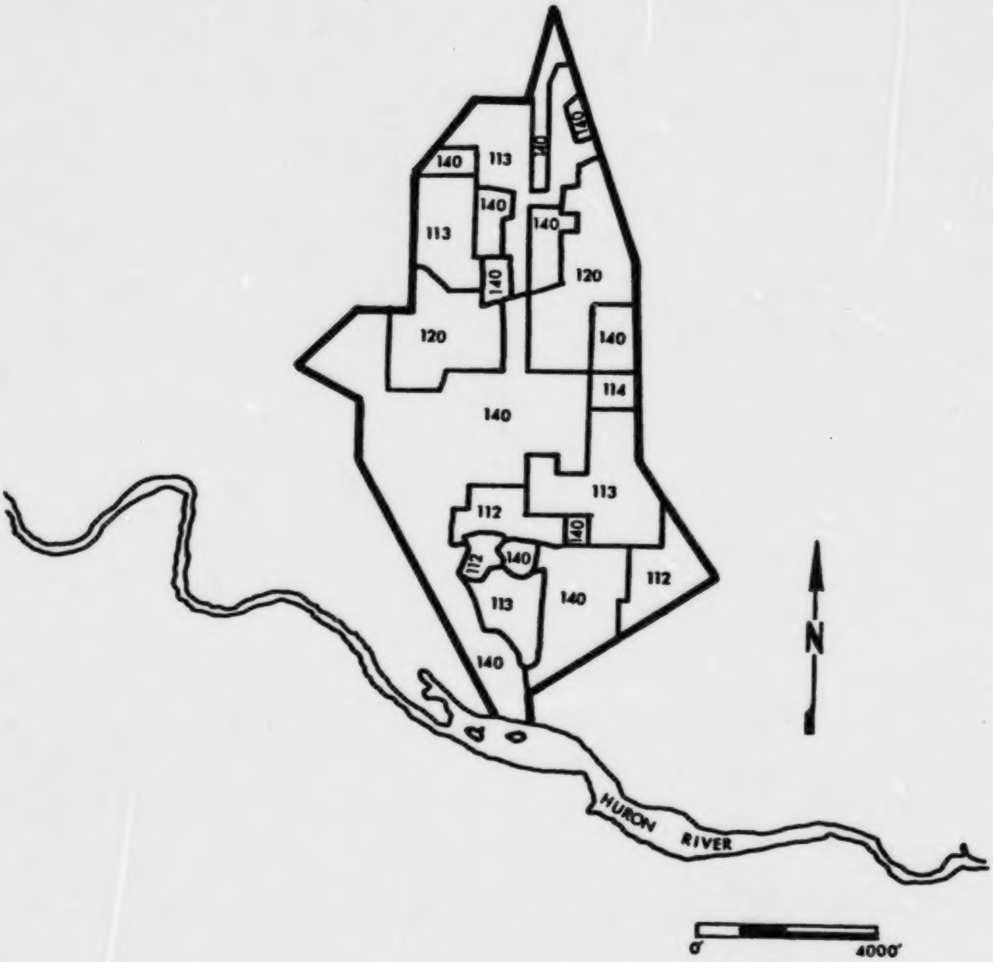

140
140
140
113
140
113
140
140
120
120
140
114
140
113
112
140
140
112
112
113
140
140
N
HURON RIVER
0'
4000'

Figure II-12. Level III: Land Use Map - North Campus Drain, Ann Arbor, Michigan

PHYSICAL DESCRIPTION OF BMP'S

General

The effectiveness of various Best Management Practices (BMP's) to improve or control water quality conditions was evaluated during this study. The BMP's under study include the use of a runoff ordinance which results in the detention of peak runoff waters, the use of naturally occurring wetlands, an on-line retention basin, and an off-line detention facility. The retention basin, wetland, and detention basin have certain basic physical descriptors which may or may not have an impact on their effectiveness. These general physical characteristics are presented in this section.

Pittsfield-Ann Arbor Retention Basin

The Pittsfield-Ann Arbor Retention Basin is located in Washtenaw County, Michigan (longtitude 83° 42' 18" and latitude 42° 14' 38", visually determined from USGS Quad). The basin was designed to provide flood relief to downstream sections of the drain. Flood relief purposes were the only factors considered in the initial design of the basin. However, the basin may also provide water quality benefits to the downstream area and Huron River. It was the objective of this study to obtain water quality data on the "as built" inherent capability of this basin to reduce pollutant levels occurring in the storm water entering the basin. Some changes in water quality are expected to occur due to sedimentation processes and possibly through biological activity.

The basin shape is shown in Figure II-13. Water enters the basin at the bottom of the figure (west) and exits at the top (east). There are two main tributaries discharging to the basin. These tributaries join into a single entrance channel several hundred feet upstream of the actual basin entrance.

A permanent water elevation of 801 is maintained in the basin with a permanent storage capacity of 914,760 cubic feet. An additional design capacity of 6,734,376 ft^3 occurs at elevation 807 with a maximum design flow of 2,916 cfs at this elevation. See Table II-6 for depth-volume relationships.

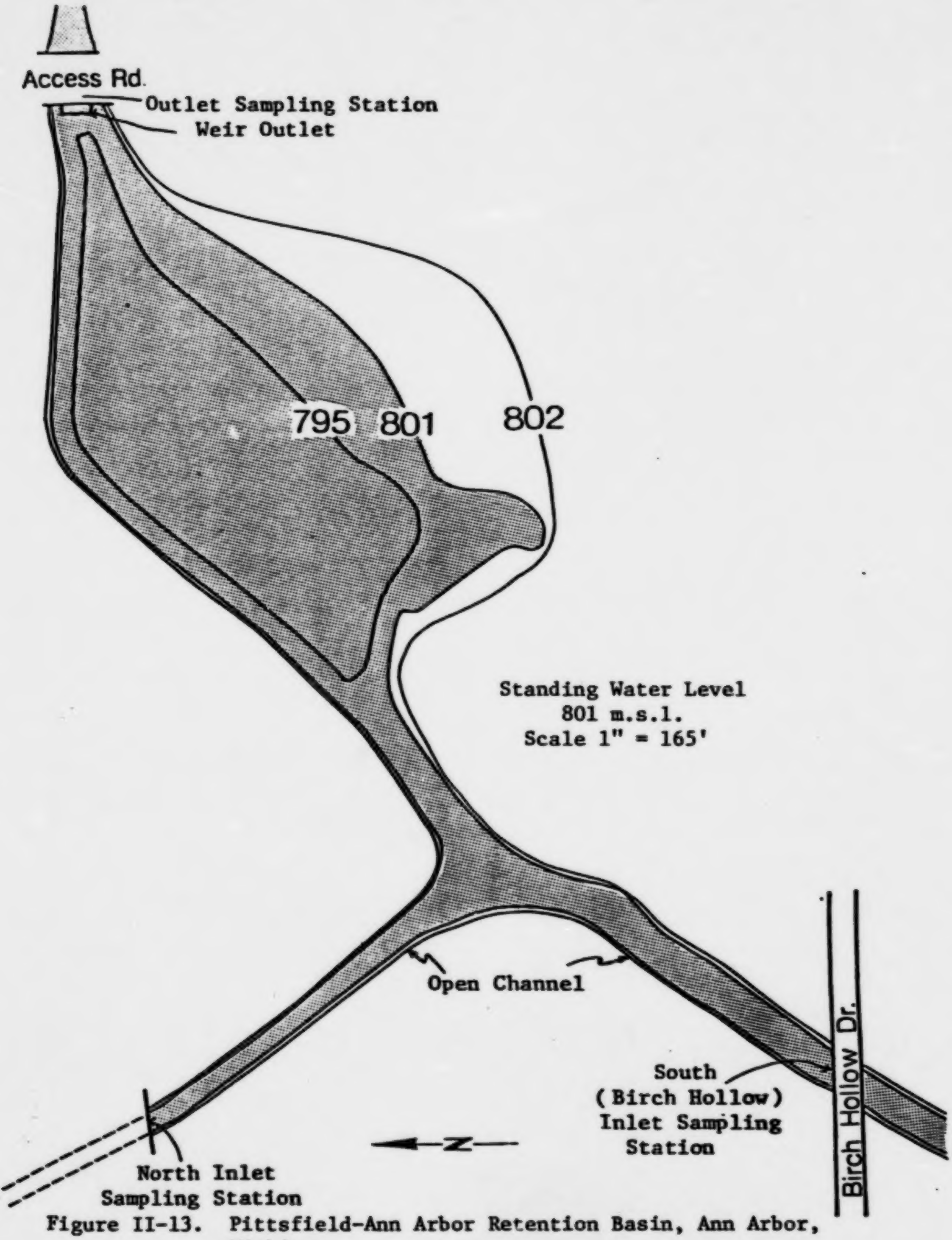

Access Rd.
Outlet Sampling Station
Weir Outlet
795
801
802
Standing Water Level
801 m.s.l.
Scale 1" = 165'
Open Channel
South
(Birch Hollow)
Inlet Sampling
Station
Birch Hollow Dr.
N
North Inlet
Sampling Station

Figure II-13. Pittsfield-Ann Arbor Retention Basin, Ann Arbor, Michigan

Table II-6 Depth-volume Relationship - Pittsfield-Ann Arbor Retention Basin

Elevation	Stage Feet	Surface Area ($ft.^2$)	Capacity (cu.ft.)	Discharge (CFS)
801	0		914,760	0
802	1	226,510	1,141,270	198
803	2	383,330	1,681,420	561
804	3	588,060	2,678,940	1,031
805	4	834,175	4,251,460	1,587
806	5	1,048,900	6,159,384	2,218
807	6	1,122,400	7,649,140	2,916

The outlet structure for this retention basin is a rectangular broadcrested weir which controls water elevation and discharge (Figure II-14). This structure was designed only to attenuate flood flows and does not severely restrict flow at low runoff rates. The overflow weir is approximately 60 feet in total length including both front and side surfaces. The depth of the water at the weir is approximately 1.5 to 3 feet measured during dry flow conditions.

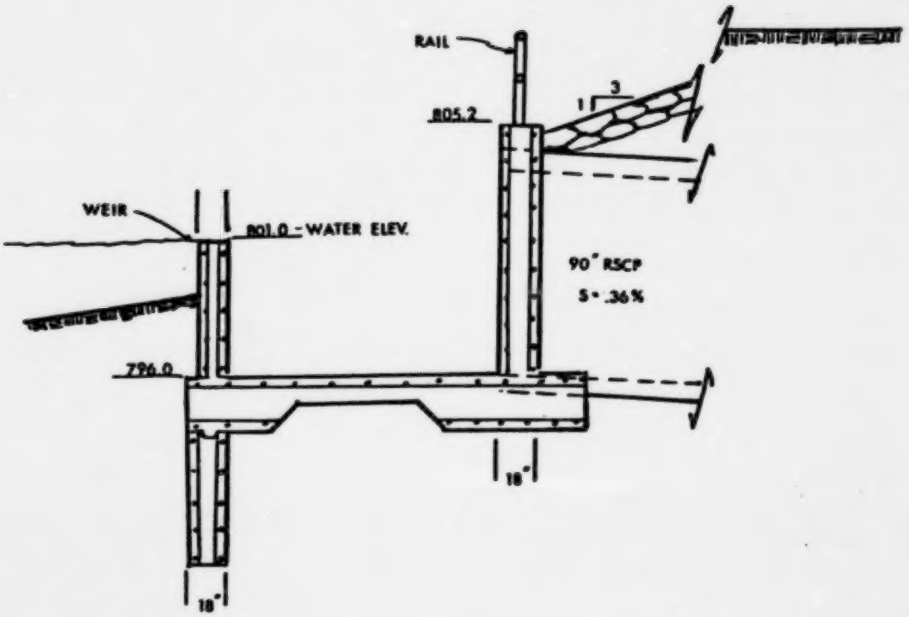

RAIL
3
1
805.2
WEIR
801.0 - WATER ELEV.
90" RSCP
S = .36%
796.0
18"
18"

Figure II-14. Pittsfield-Ann Arbor Retention Basin Outlet Structure, Ann Arbor, Michigan

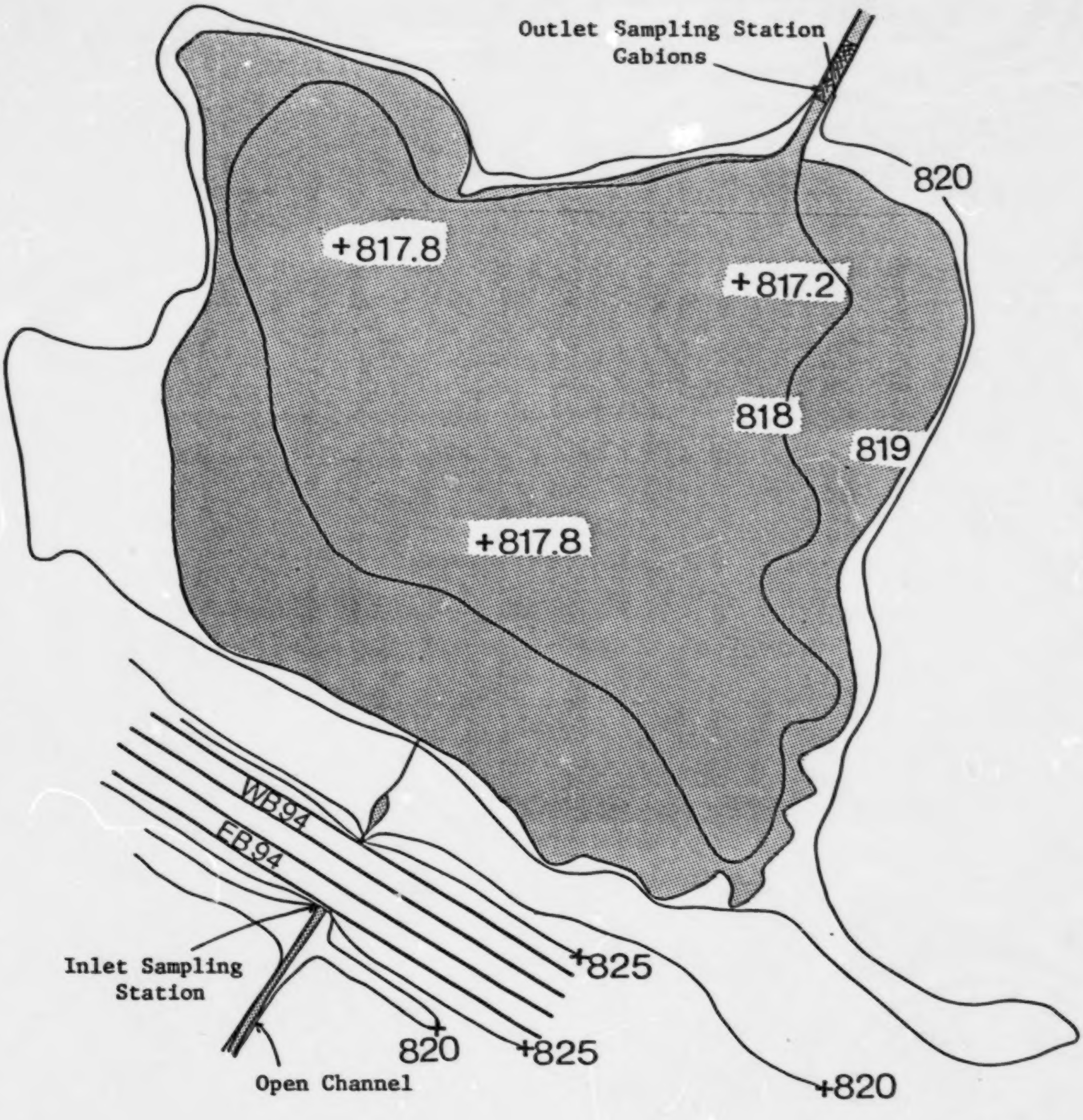
Swift Run Wetland

The Swift Run Wetlands is also located in Washtenaw County, Michigan (longitude 83° 42' 13" and latitude 42° 14' 7" based on visual approximation from U.S.G.S. map of the area). This naturally occuring wetland was investigated as a BMP for its capability to reduce total suspended solids, BOD, nutrients and metals contained in stormwater runoff from the upstream townhouse development and landfill.

The shape of the wetlands is illustrated in Figure II-15. The average depth ranges between one and two feet. The wetlands is designed to sustain a permanent water elevation of 819 with a permanent overflow structure which will handle flows generating heads up to 3 feet or elevation 822 (See Table II-7). This yields a storage volume of approximately 2.6 x 10^6 cubic feet.

Table II-7. Depth Volume - Discharge Relationship
Swift Run Wetlands

Elevation	Stage Feet	Discharge CFS	Volume (cu.ft.)	Surface Area ft.^{2}
819	0	0	630,000	419,900
820	1	16	927,500	615,800
821	2	66	1,647,200	823,500
822	3	166	2,621,000	1,077,000


Outlet Sampling Station
Gabions
820
+817.8
+817.2
818
819
+817.8
WB94
EB94
Inlet Sampling Station
+825
820
+825
Open Channel
+820

Standing Water Level: 819 m.s.l.
1" = 150'

N

Figure II-15. Swift Run Wetland BMP, Ann Arbor, Michigan

This storage volume is sufficient to maintain outlet flows from the wetlands at rates equal to or less than 160 cfs. capacity of the downstream storm sewer during a 25 year, 24 hr. duration rainfall. The controlling outlet structure is a trapezoidal weir with gabions lining the sides and bottom of the channel as illustrated in Figure II-16.

Traver Creek Retention Basin

The Traver Creek retention basin is located in Washtenaw County, Michigan (longitude 83° 40' 03", latitude 24° 32' 00"). This basin was originally designed to provide detention of water for flood control and water quality improvement by sedimentation. The basin was designed as an off line basin which received water during high flow periods via a diversion channel. During high flows, the capacity of an overflow structure located in the normal creek bed would be exceeded, resulting in water being diverted to the basin. The purpose of using this approach was to provide a dry basin during dry weather, allow for the maintaining of normal dry weather creek flows, and to allow for increased holding time in the basin of the high flow waters by severely restricting the flow from the basin. Figures II-17, 18, 19 show the basin area, the outlet structure in the basin, and the creek dry flow bypass structure.

Several factors changed the original basin design and affected the basin conditions. The most important factor to this study was the construction schedule. Due to delays,

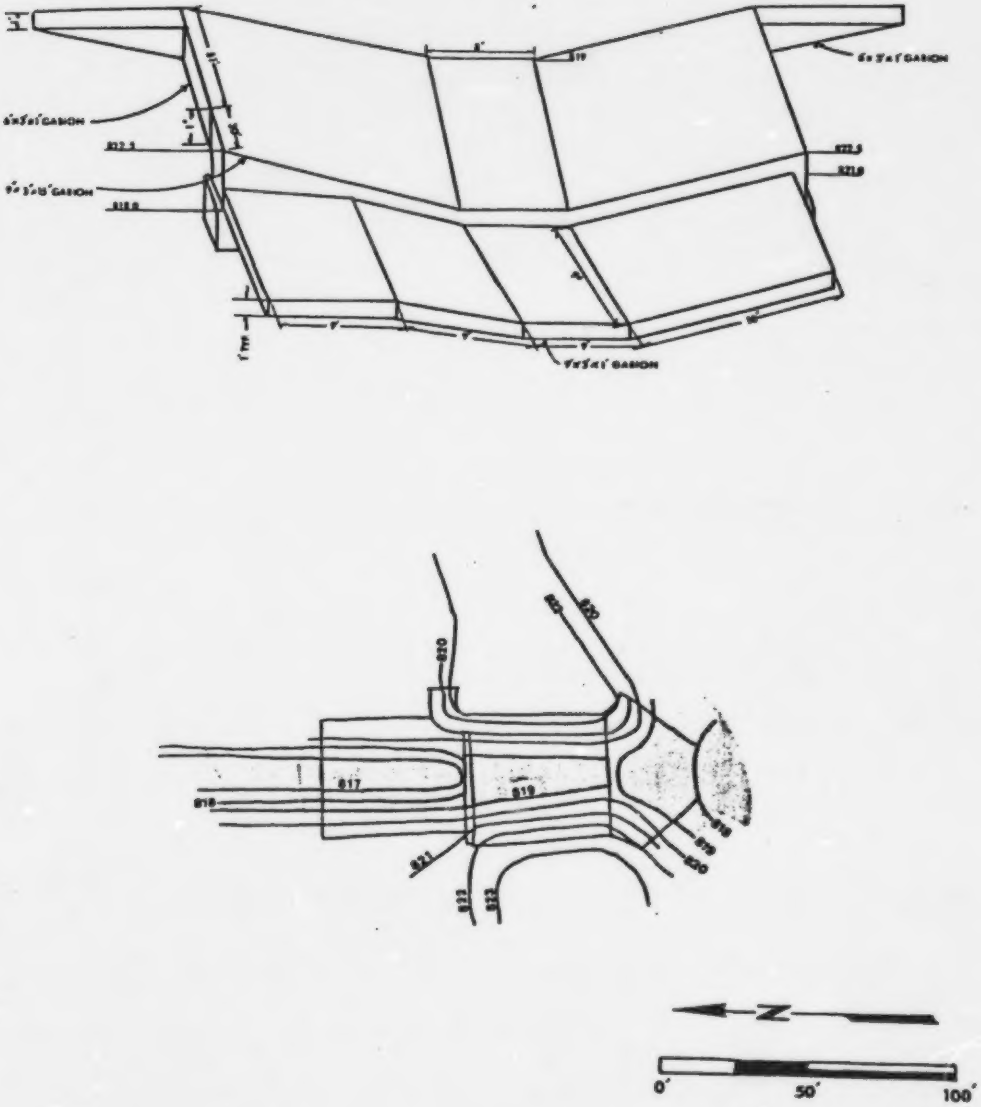
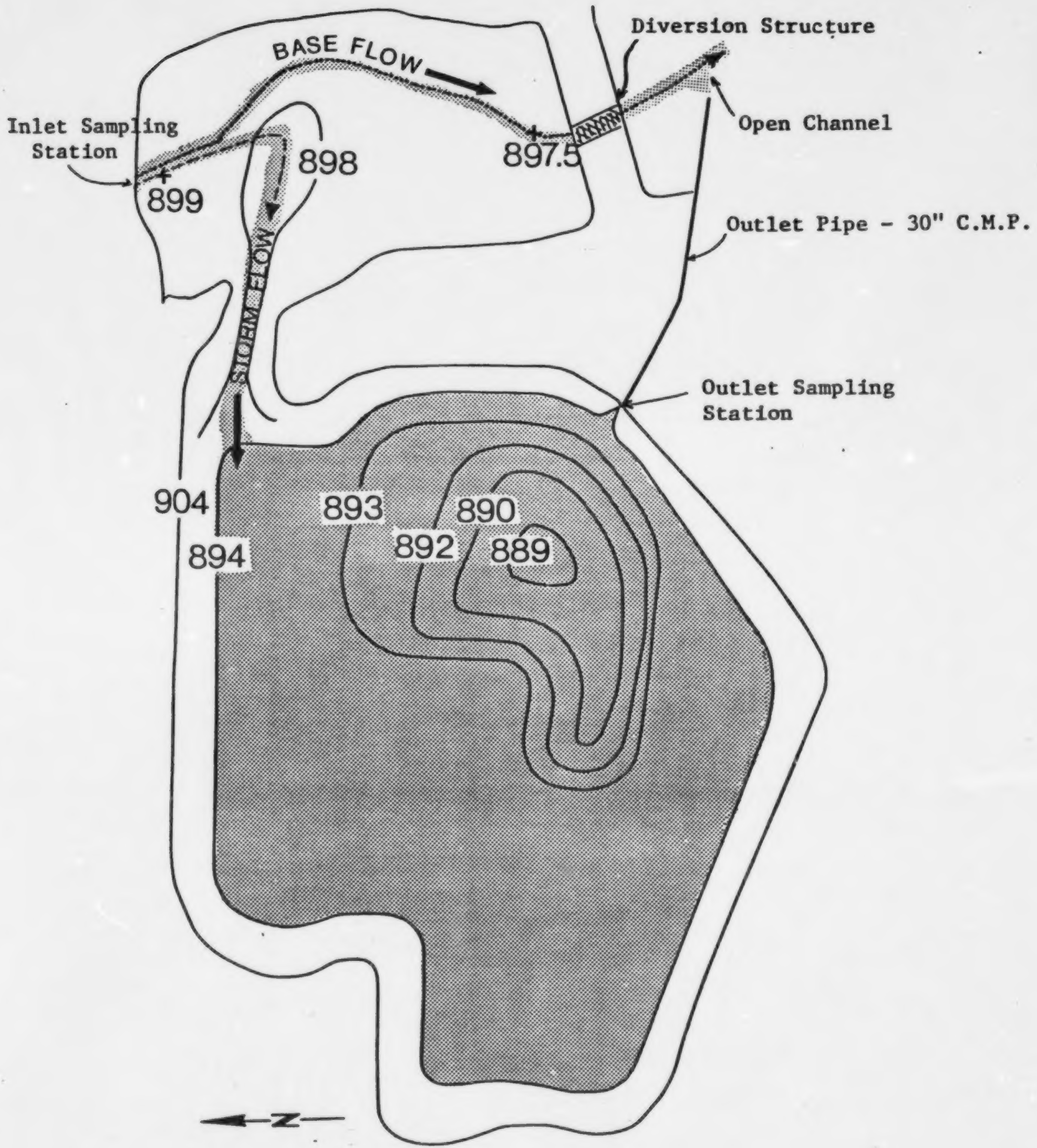

822.5
822.5
821.0
818.0
819
GABION
GABION
GABION
GABION
820
820
820
817
818
819
821
822
822
818
819
820
N
0'
50'
100'

Figure II-16. Swift Run Wetland Outlet Structure,
Ann Arbor, Michigan


Diversion Structure
BASE FLOW
Open Channel
Inlet Sampling Station
898
897.5
899
Outlet Pipe - 30" C.M.P.
STORM FLOW
Outlet Sampling Station
904
893
890
892
889
894
N

Standing Water Level: 894 m.s.l.
1" = 150'

Figure II-17. Traver Creek Detention Basin, Ann Arbor, Michigan

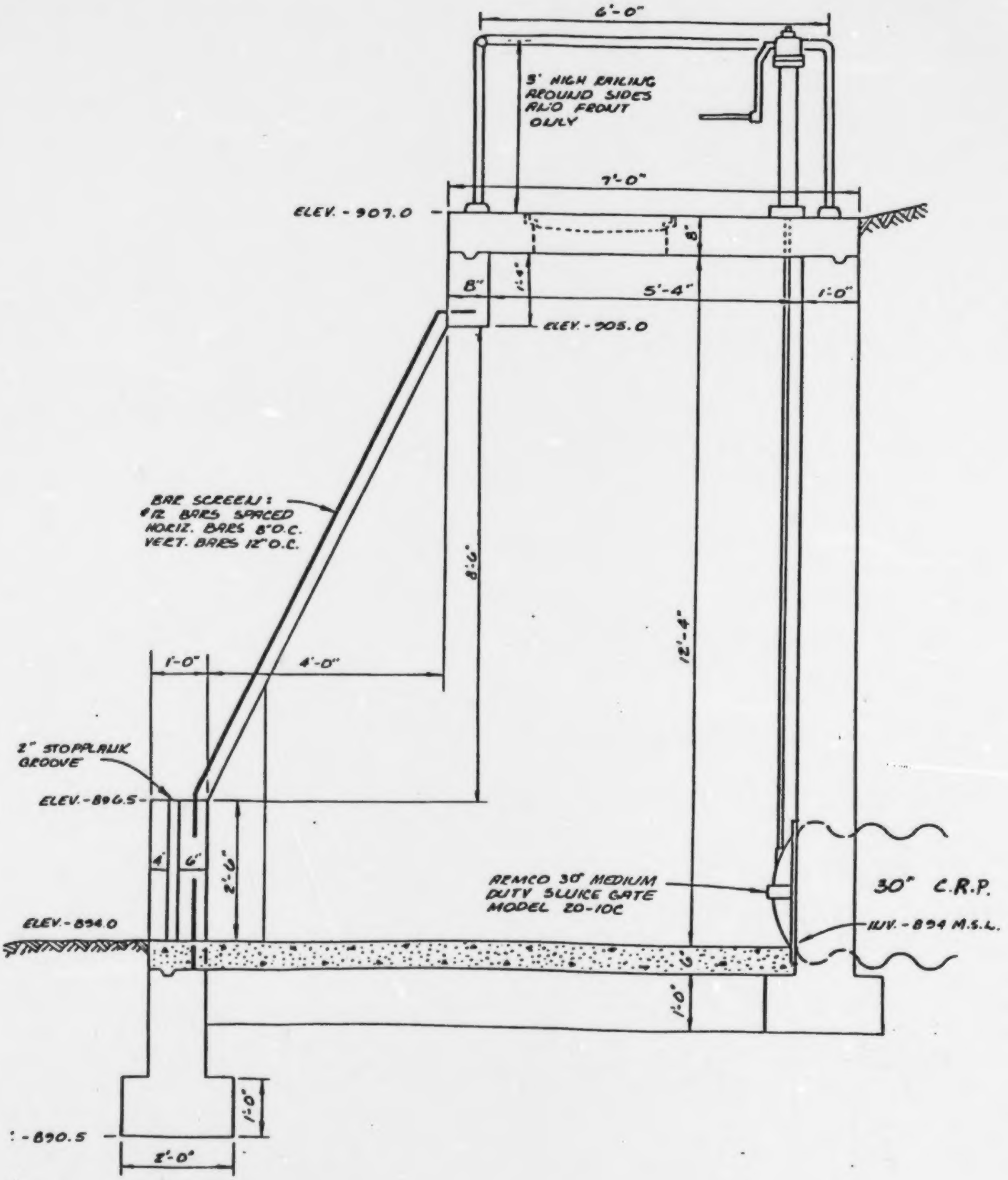

6'-0"
3' HIGH RAILING AROUND SIDES AND FRONT ONLY
7'-0"
ELEV. - 907.0
8"
8"
1'-4"
5'-4"
1'-0"
ELEV. - 905.0
BAR SCREEN: #12 BARS SPACED HORIZ. BARS 8" O.C. VERT. BARS 12" O.C.
8'-6"
12'-4"
1'-0"
4'-0"
2" STOPPLANK GROOVE
ELEV. - 896.5
4"
6"
2'-6"
REMCO 30" MEDIUM DUTY SLUICE GATE MODEL 20-10C
30" C.R.P.
INV. - 894 M.S.L.
ELEV. - 894.0
6"
1'-0"
1'-0"
: - 890.5
2'-0"

Figure II-18. Traver Creek Detention Basin Outlet Structure, Ann Arbor, Michigan

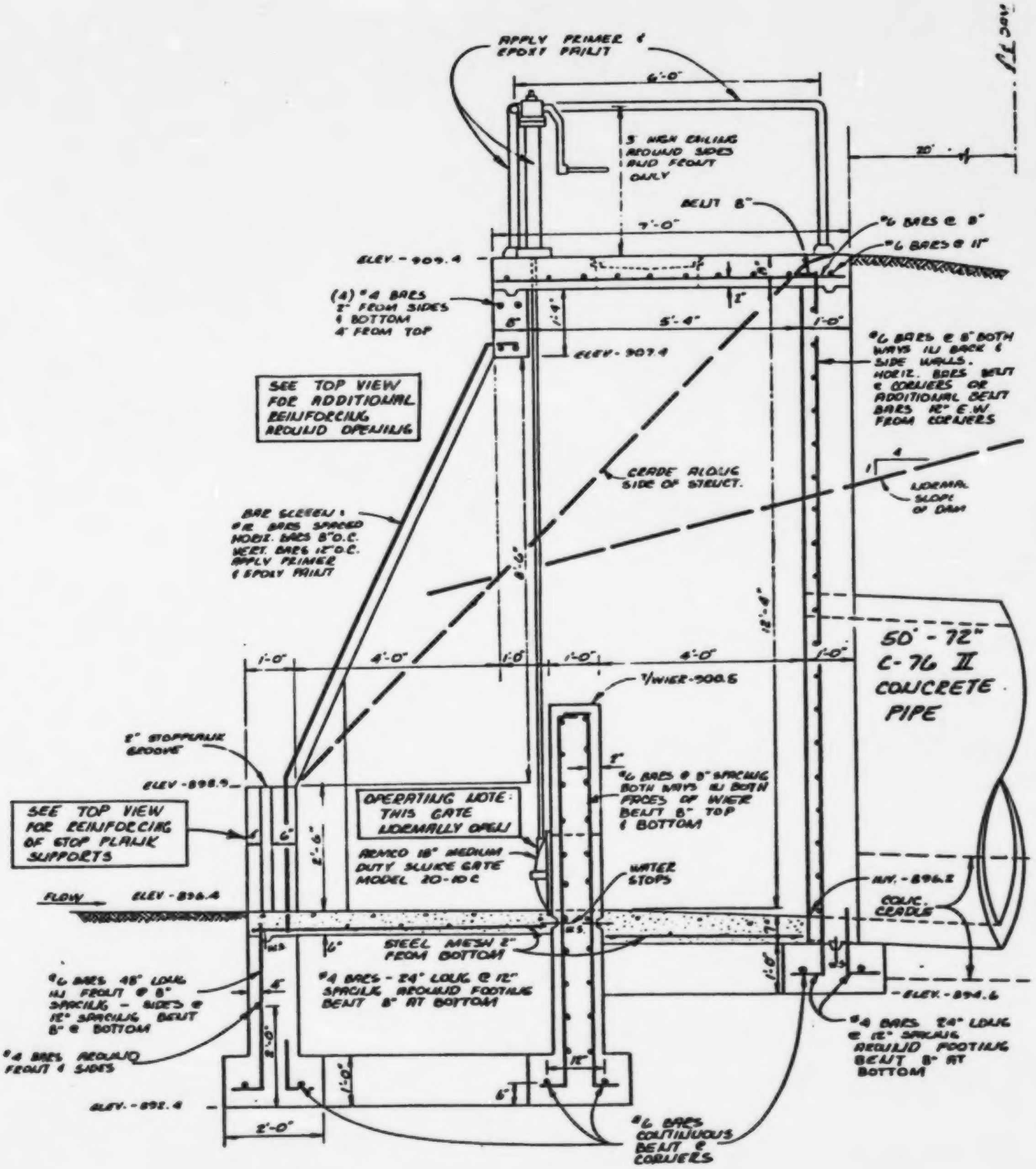

APPLY PRIMER & EPOXY PAINT
6'-0"
3' HIGH RAILING AROUND SIDES AND FRONT ONLY
℄ DAM
20'
BENT 8"
7'-0"
#6 BARS @ 8"
#6 BARS @ 11"
ELEV - 909.4
(4) #4 BARS 2" FROM SIDES & BOTTOM 4" FROM TOP
8"
1'-4"
1"
5'-4"
1'-0"
ELEV - 907.4
#6 BARS @ 8" BOTH WAYS IN BACK & SIDE WALLS. HORIZ. BARS BENT @ CORNERS OR ADDITIONAL BENT BARS 12" E.W. FROM CORNERS
SEE TOP VIEW FOR ADDITIONAL REINFORCING AROUND OPENING
GRADE ALONG SIDE OF STRUCT.
4
1
NORMAL SLOPE OF DAM
BAR SCREEN: #12 BARS SPACED HORIZ. BARS 8" O.C. VERT. BARS 12" O.C. APPLY PRIMER & EPOXY PAINT
9'-6"
12'-8"
1'-0"
4'-0"
1'-0"
1'-0"
4'-0"
1'-0"
50' - 72" C-76 II CONCRETE PIPE
▽ WIER - 900.6
2" STOPPLANK GROOVE
ELEV - 898.9
8"
#6 BARS @ 8" SPACING BOTH WAYS IN BOTH FACES OF WIER BENT 8" TOP & BOTTOM
SEE TOP VIEW FOR REINFORCING OF STOP PLANK SUPPORTS
6"
2'-6"
OPERATING NOTE: THIS GATE NORMALLY OPEN
ARMCO 18" MEDIUM DUTY SLUICE GATE MODEL 20-10C
WATER STOPS
INV. - 896.2
CONC. CRADLE
FLOW
ELEV - 896.4
W.S.
6"
STEEL MESH 2" FROM BOTTOM
1'-0"
#6 BARS 48" LONG IN FRONT @ 8" SPACING - SIDES @ 12" SPACING BENT 8" @ BOTTOM
4"
#4 BARS - 24" LONG @ 12" SPACING AROUND FOOTING BENT 8" AT BOTTOM
ELEV. - 894.6
2'-0"
#4 BARS AROUND FRONT & SIDES
1'-0"
12"
#4 BARS 24" LONG @ 12" SPACING AROUND FOOTING BENT 8" AT BOTTOM
6"
ELEV. - 892.4
2'-0"
#6 BARS CONTINUOUS BENT @ CORNERS

Figure II-19. Traver Creek Detention Basin Bypass Structure, Ann Arbor, Michigan

the bypass structure was not completed until after the monioring work was complete. The basin was complete, however, along with the outlet structure. Therefore, the basin was operating as an on-line retention basin during this study. All flow, both dry and wet weather, was diverted through the basin for this study. The other factor affecting the study was that while designed as a dry basin, the final construction elevations resulted in standing water averaging approximately 2 feet deep being present in the basin. Therefore, the dry detention basin was actually a wet retention basin during the study. Table II-8 shows the depth-area-volume-discharge relationships for this basin using the actual conditions observed during the project.

One other major factor influenced the final design, although it did not affect this particular study. The original design called for a small by-pass structure capable of carrying only the small flows during dry weather. All runoff water would be diverted to the basin and released at a slow rate. Unfortunately, due to the proximity of the expressway the Highway Department required a change in design basis to provide capacity for the 1 in 200 year storm. Thus, significant increases in both the structural components of the two outlet locations and in flow capacity were required. The resulting structures are much larger than would be used in a normal design of this type.

Table II-8. Depth Volume - Discharge Relationship
Traver Creek Retention Basin

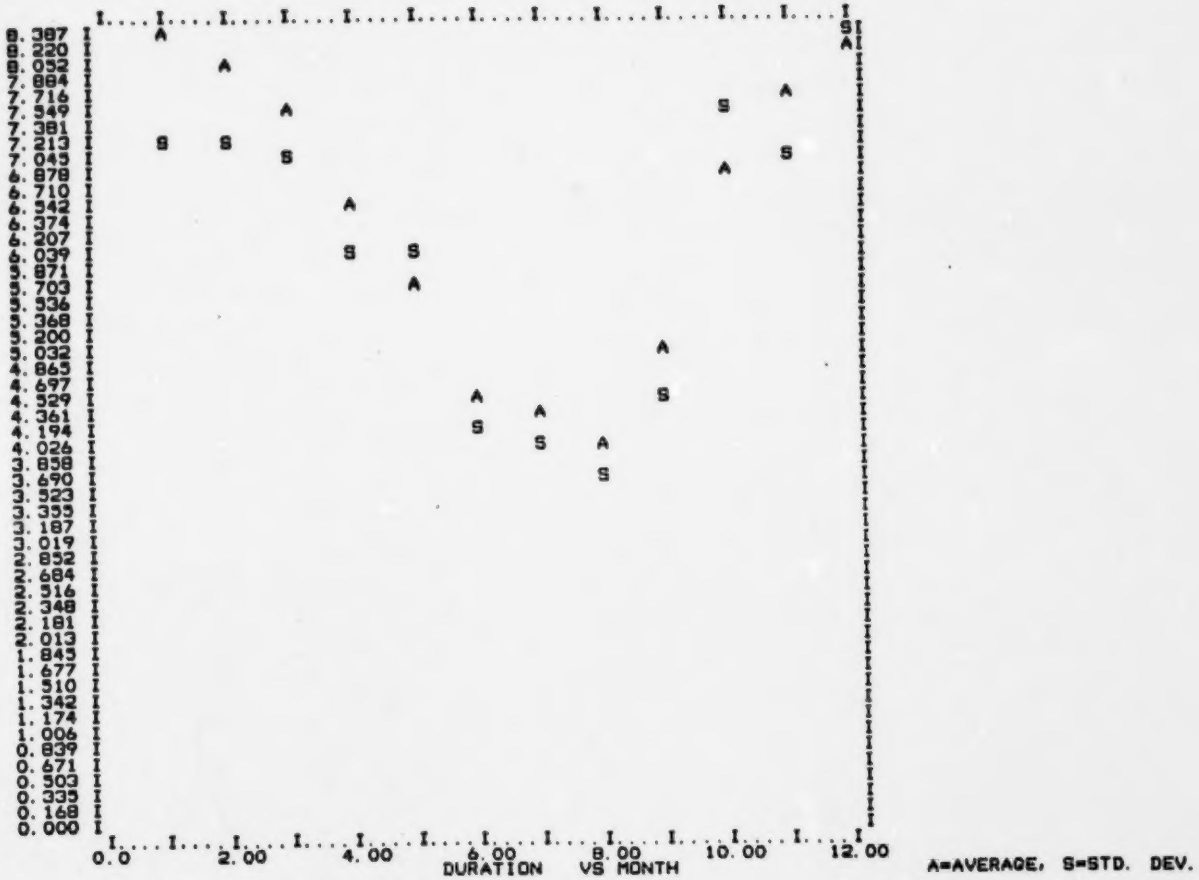
Elevation	Stage Feet	Discharge CFS	Volume (cu.ft.)	Surface Area ft.
894	0	0	512,000	290,000
896	2	5.8	1,116,000	308,000
898	4	6.7	1,756,000	326,000
900	6	10.2	2,432,000	344,000

DETAILED RAINFALL ANALYSIS - ANN ARBOR, MICHIGAN

Hourly precipitation data was obtained from the National Climatic Center for Weather Service station number 200230, Ann Arbor - University of Michigan, for the period of record, 1948-1978. This data was analyzed by the SYNOP program, with the graphical results being shown in Figures II-20 through II-31. The statistics were computed using an interevent time of five dry hours, producing a coefficient of variation for delta (the calculated interevent period) of 1.005. The coefficient of variation resulting from the EPA recommended three hour interevent time was 1.132, so the longer interval was used.

Average storm duration (hrs.), intensity (in.hr.), volume (in.) and interevent time period, delta, (hrs.) are shown for each month in Figures II-20 through II-23. The standard of deviation for these parameters are also plotted.

Average storm duration, intensity, volume, and delta for the period of record are plotted as a frequency distribution in Figures II-24 through II-27. These parameters are plotted vs. return period in years in Figures II-28 through II-31.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7.213
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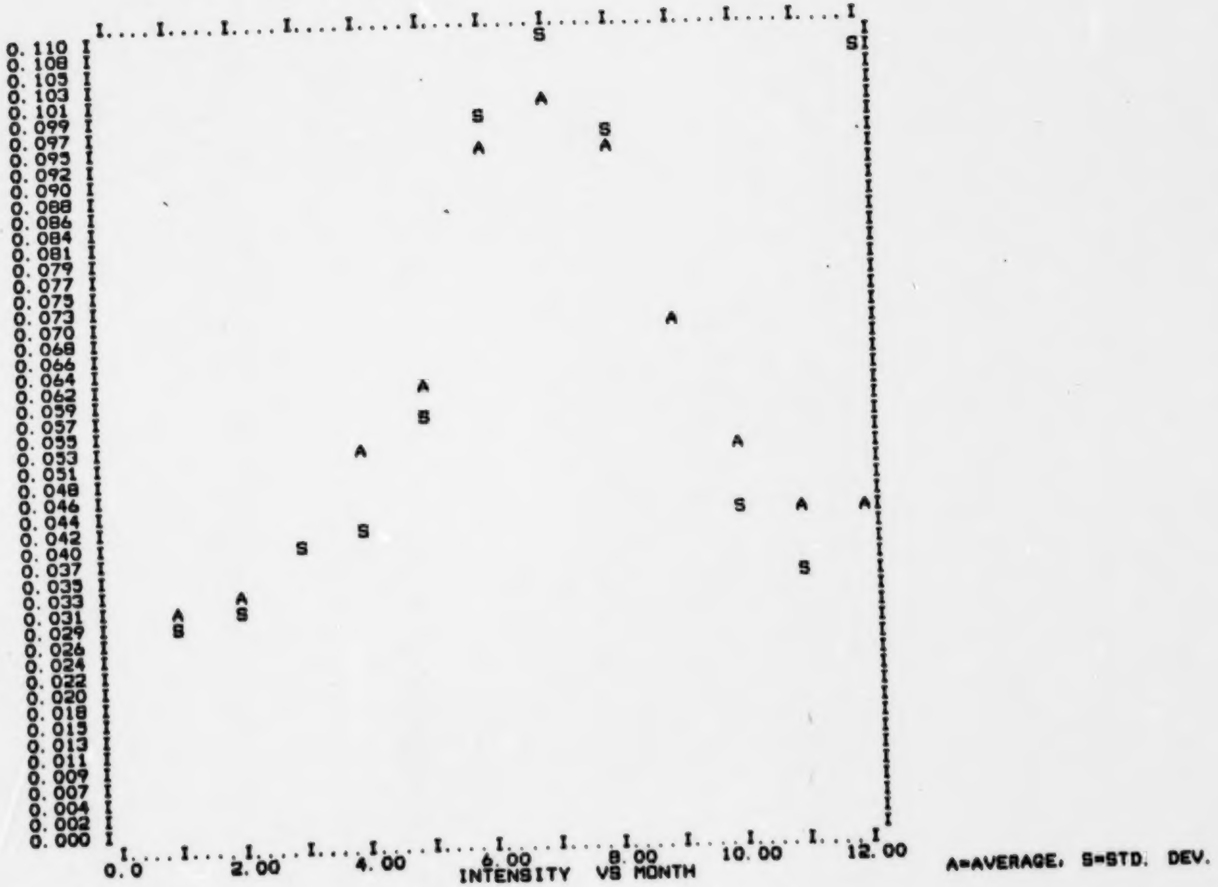
6.374
6.207
6.039
5.871
5.703
5.536
5.368
5.200
5.032
4.865
4.697
4.529
4.361
4.194
4.026
3.858
3.690
3.523
3.355
3.187
3.019
2.852
2.684
2.516
2.348
2.181
2.013
1.845
1.677
1.510
1.342
1.174
1.006
0.839
0.671
0.503
0.335
0.168
0.000
0.0
2.00
4.00
6.00
8.00
10.00
12.00
DURATION VS MONTH
A=AVERAGE, S=STD. DEV.

Figure II-20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0.097
0.095
0.092
0.090
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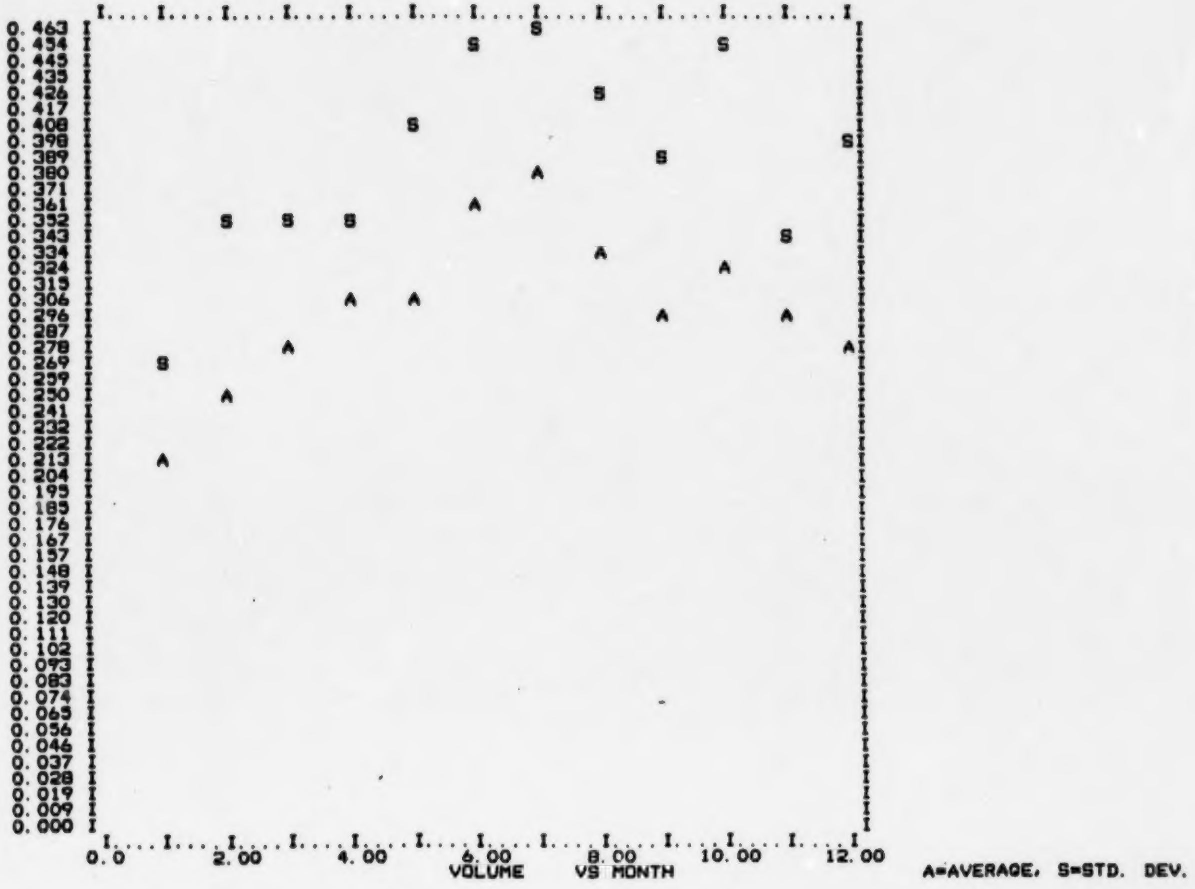
0.081
0.079
0.077
0.075
0.073
0.070
0.068
0.066
0.064
0.062
0.059
0.057
0.055
0.053
0.051
0.048
0.046
0.044
0.042
0.040
0.037
0.035
0.033
0.031
0.029
0.026
0.024
0.022
0.020
0.018
0.015
0.013
0.011
0.009
0.007
0.004
0.002
0.000
0.0
2.00
4.00
6.00
8.00
10.00
12.00
INTENSITY VS MONTH
A=AVERAGE, S=STD. DEV.

Figure II-21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0.380
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0.343
0.334
0.324
0.315
0.306
0.296
0.287
0.278
0.269
0.259
0.250
0.241
0.232
0.222
0.213
0.204
0.195
0.185
0.176
0.167
0.157
0.148
0.139
0.130
0.120
0.111
0.102
0.093
0.083
0.074
0.065
0.056
0.046
0.037
0.028
0.019
0.009
0.000
0.0
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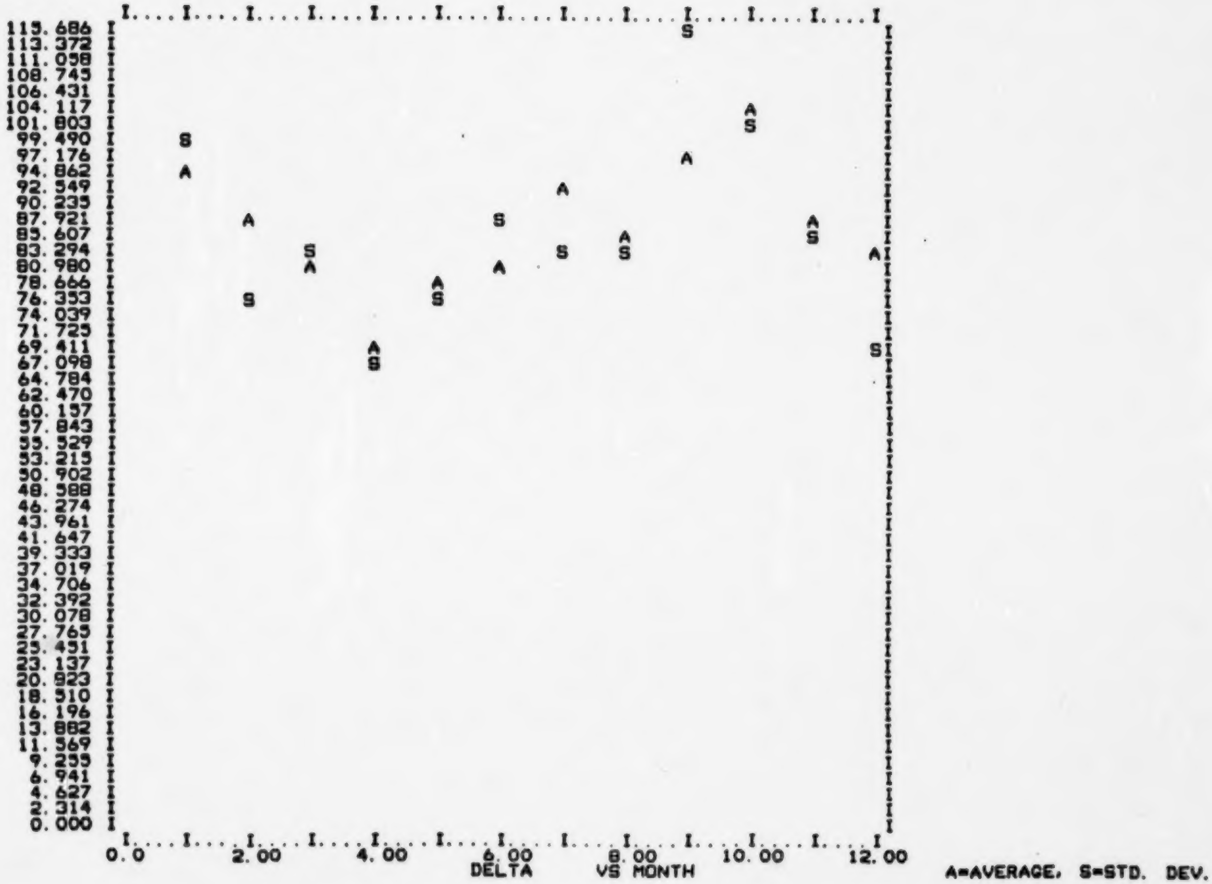
6.00
8.00
10.00
12.00
VOLUME VS MONTH
A=AVERAGE, S=STD. DEV.

Figure II-22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113.372
111.058
108.745
106.431
104.117
101.803
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97.176
94.862
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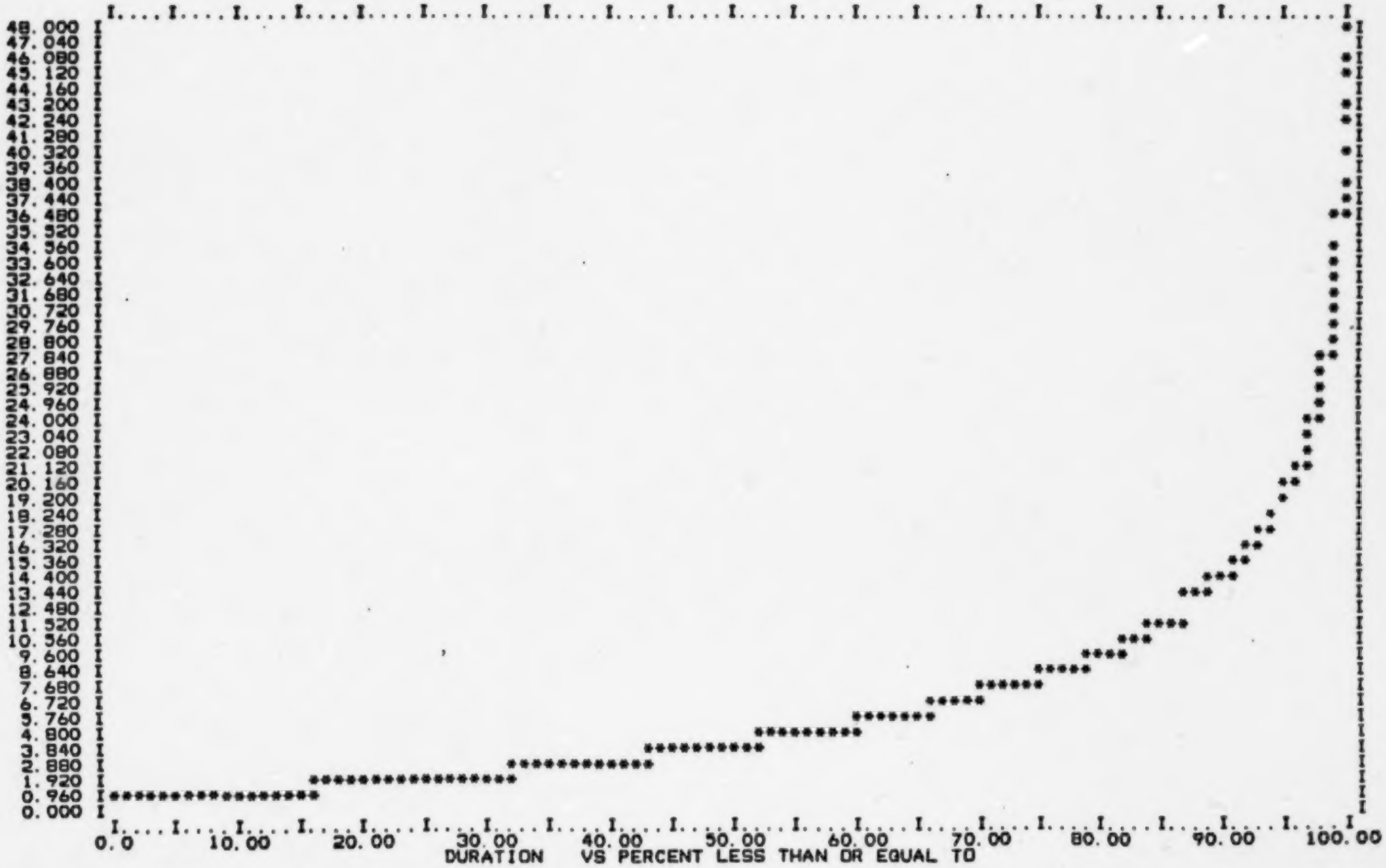
87.921
85.607
83.294
80.980
78.666
76.353
74.039
71.725
69.411
67.098
64.784
62.470
60.157
57.843
55.529
53.215
50.902
48.588
46.274
43.961
41.647
39.333
37.019
34.706
32.392
30.078
27.765
25.451
23.137
20.923
18.510
16.196
13.882
11.569
9.255
6.941
4.627
2.314
0.000
0.0
2.00
4.00
6.00
8.00
10.00
12.00
DELTA VS MONTH
A=AVERAGE, S=STD. DEV.

Figure II-23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39.360
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35.520
34.560
33.600
32.640
31.680
30.720
29.760
28.800
27.840
26.880
25.920
24.960
24.000
23.040
22.080
21.120
20.160
19.200
18.240
17.280
16.320
15.360
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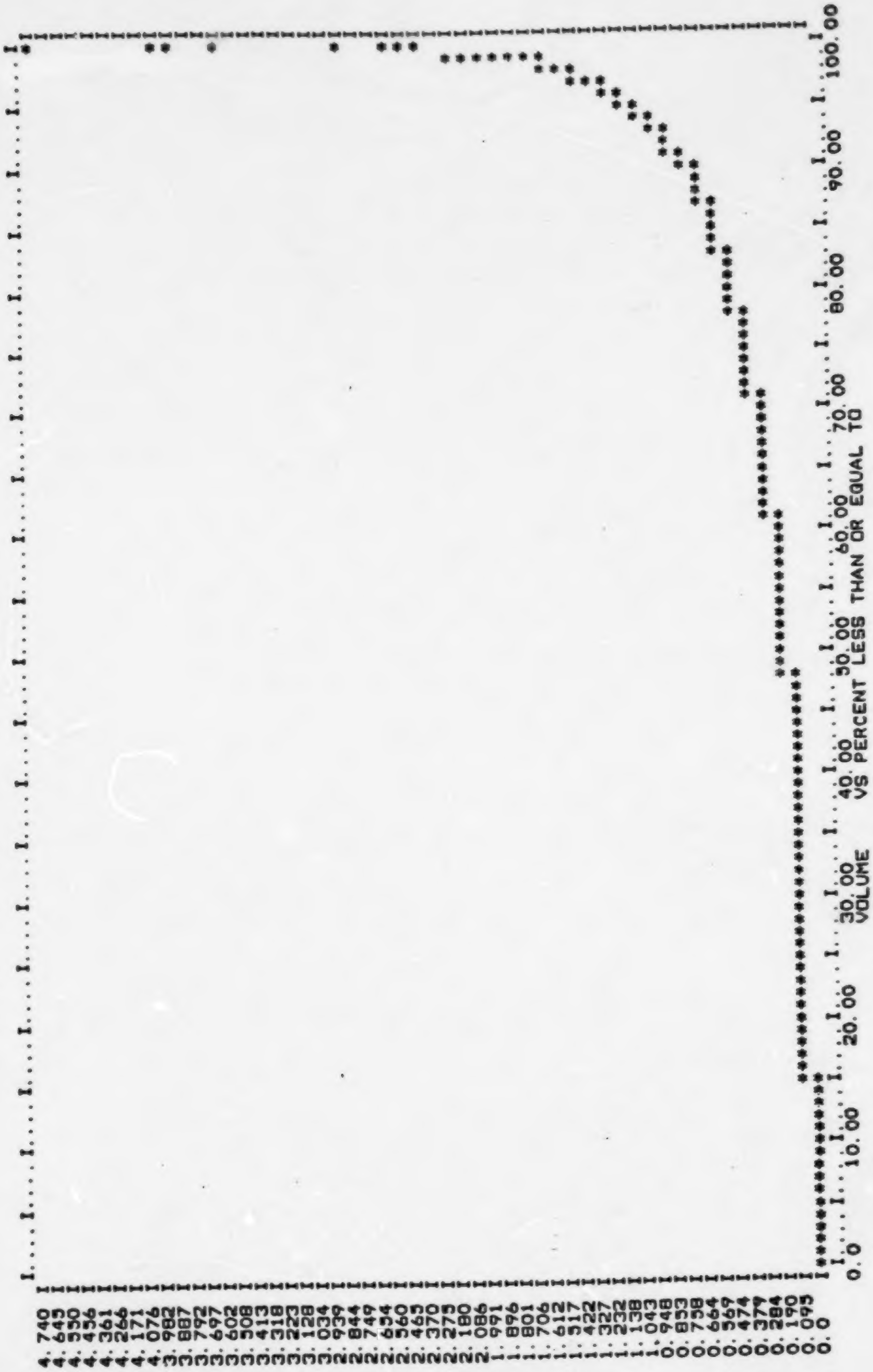
13.440
12.480
11.520
10.560
9.600
8.640
7.680
6.720
5.760
4.800
3.840
2.880
1.920
0.960
0.000
0.0
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
DURATION VS PERCENT LESS THAN OR EQUAL TO

Figure II-24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3.508
3.413
3.318
3.223
3.128
3.034
2.939
2.844
2.749
2.654
2.560
2.465
2.370
2.275
2.180
2.086
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1.896
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1.706
1.612
1.517
1.422
1.327
1.232
1.138
1.043
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0.853
0.758
0.664
0.569
0.474
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0.284
0.190
0.095
0.0
0.0
10.00
20.00
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80.00
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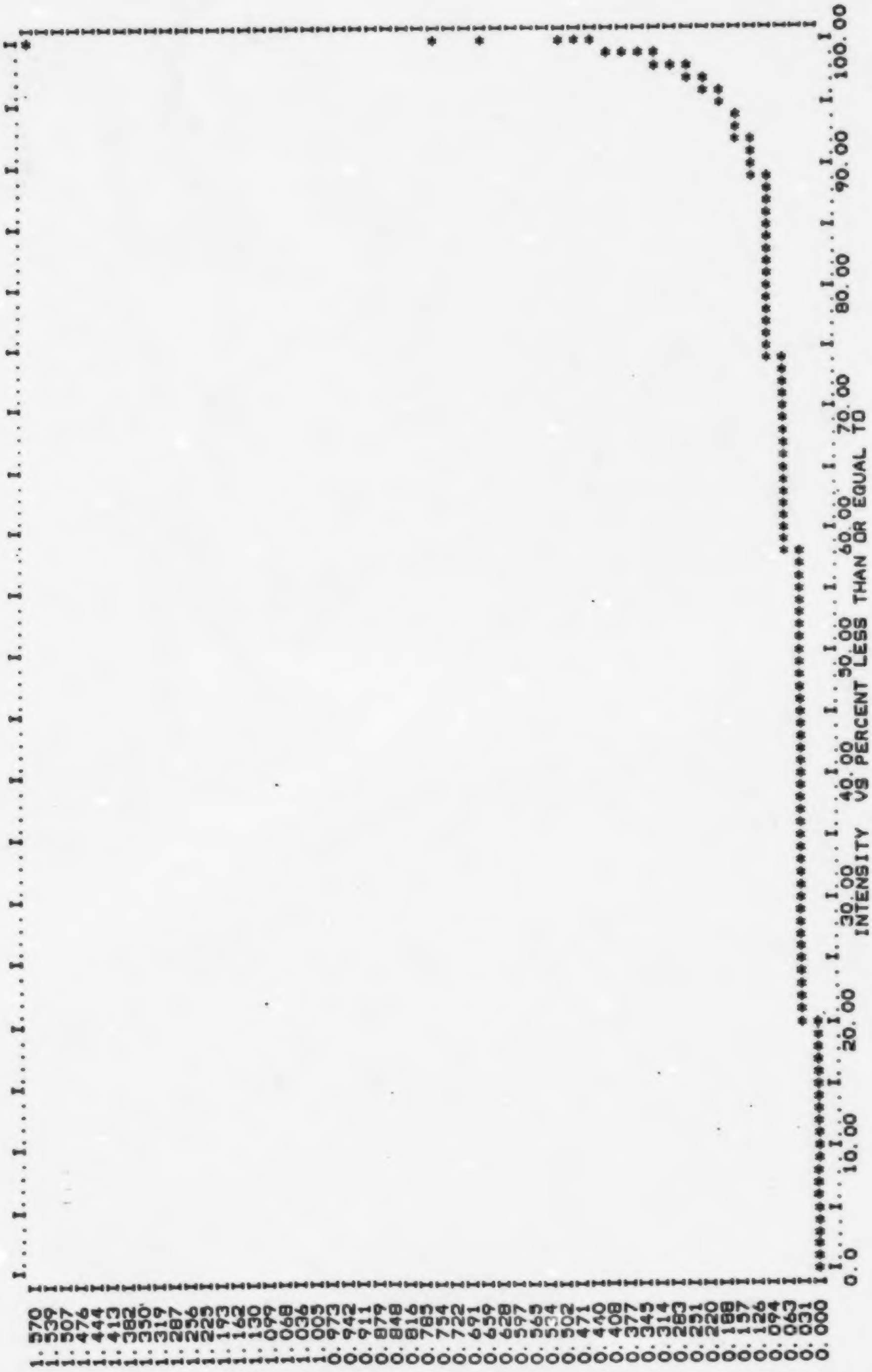
100.00
VOLUME VS PERCENT LESS THAN OR EQUAL TO

Figure II-25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1.193
1.162
1.130
1.099
1.068
1.036
1.005
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0.942
0.911
0.879
0.848
0.816
0.785
0.754
0.722
0.691
0.659
0.628
0.597
0.565
0.534
0.502
0.471
0.440
0.408
0.377
0.345
0.314
0.283
0.251
0.220
0.188
0.157
0.126
0.094
0.063
0.031
0.000
0.0
10.00
20.00
30.00
40.00
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70.00
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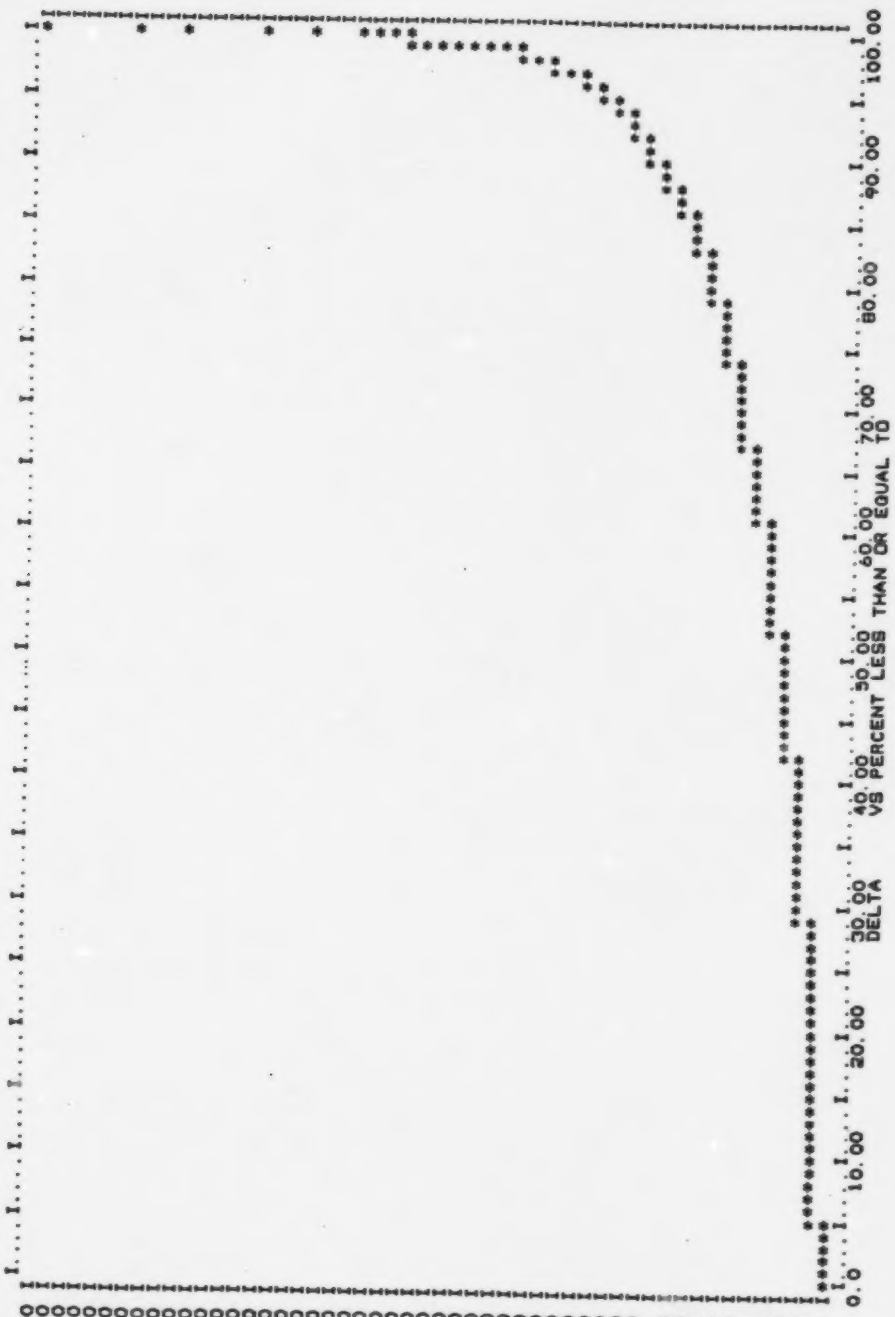
100.00
INTENSITY VS PERCENT LESS THAN OR EQUAL TO

Figure II-26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640.840
623.520
606.200
588.880
571.560
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536.920
519.600
502.280
484.960
467.640
450.320
433.000
415.680
398.360
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346.400
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311.760
294.440
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259.800
242.480
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190.521
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155.880
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121.240
103.920
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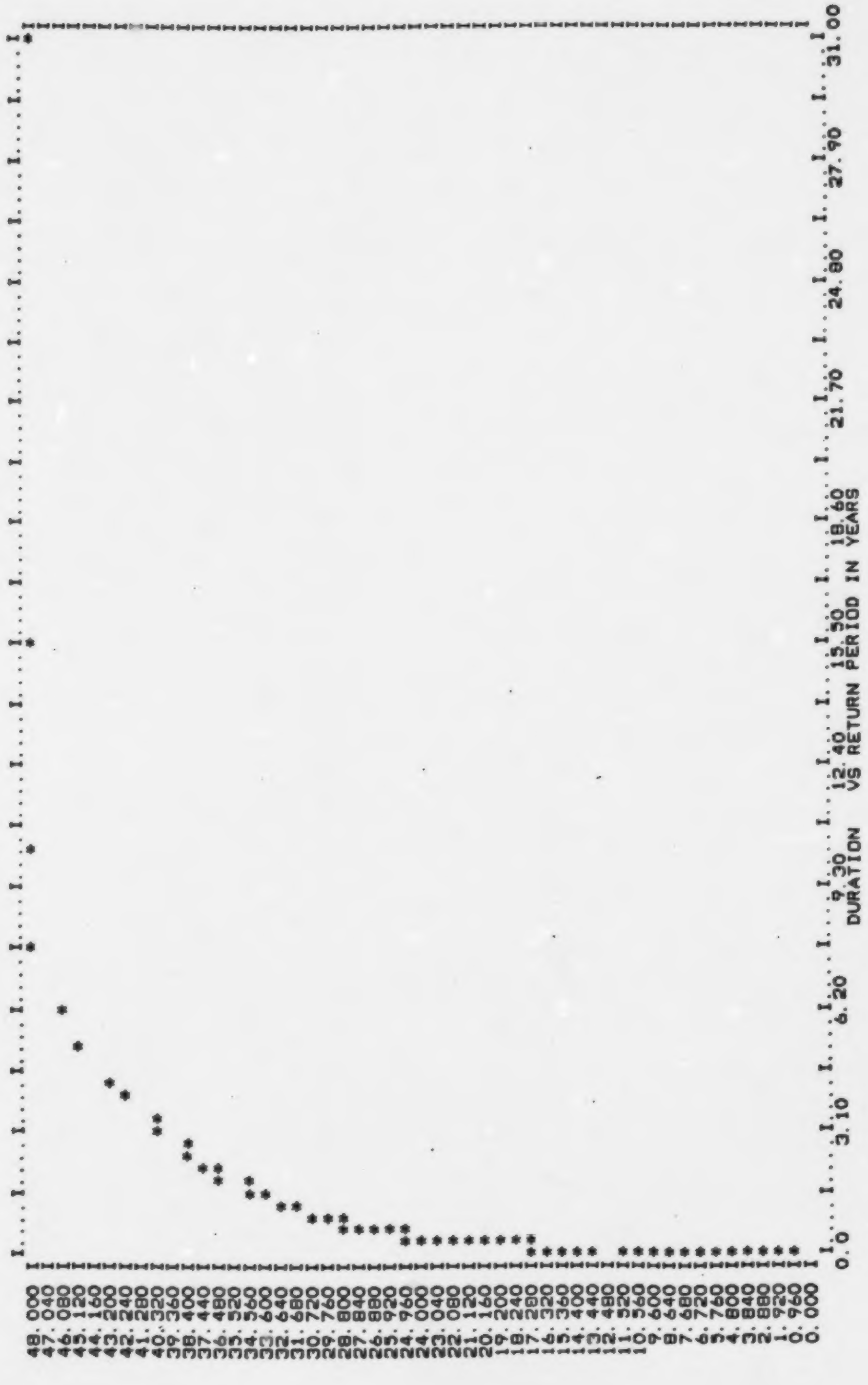
DELTA VS PERCENT LESS THAN OR EQUAL TO

Figure II-27


DURATION VS RETURN PERIOD IN YEARS
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12.40
15.50
18.60
21.70
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27.90
31.00
48.000
47.040
46.080
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43.200
42.240
41.280
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32.640
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30.720
29.760
28.800
27.840
26.880
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13.440
12.480
11.520
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5.760
4.800
3.840
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1.920
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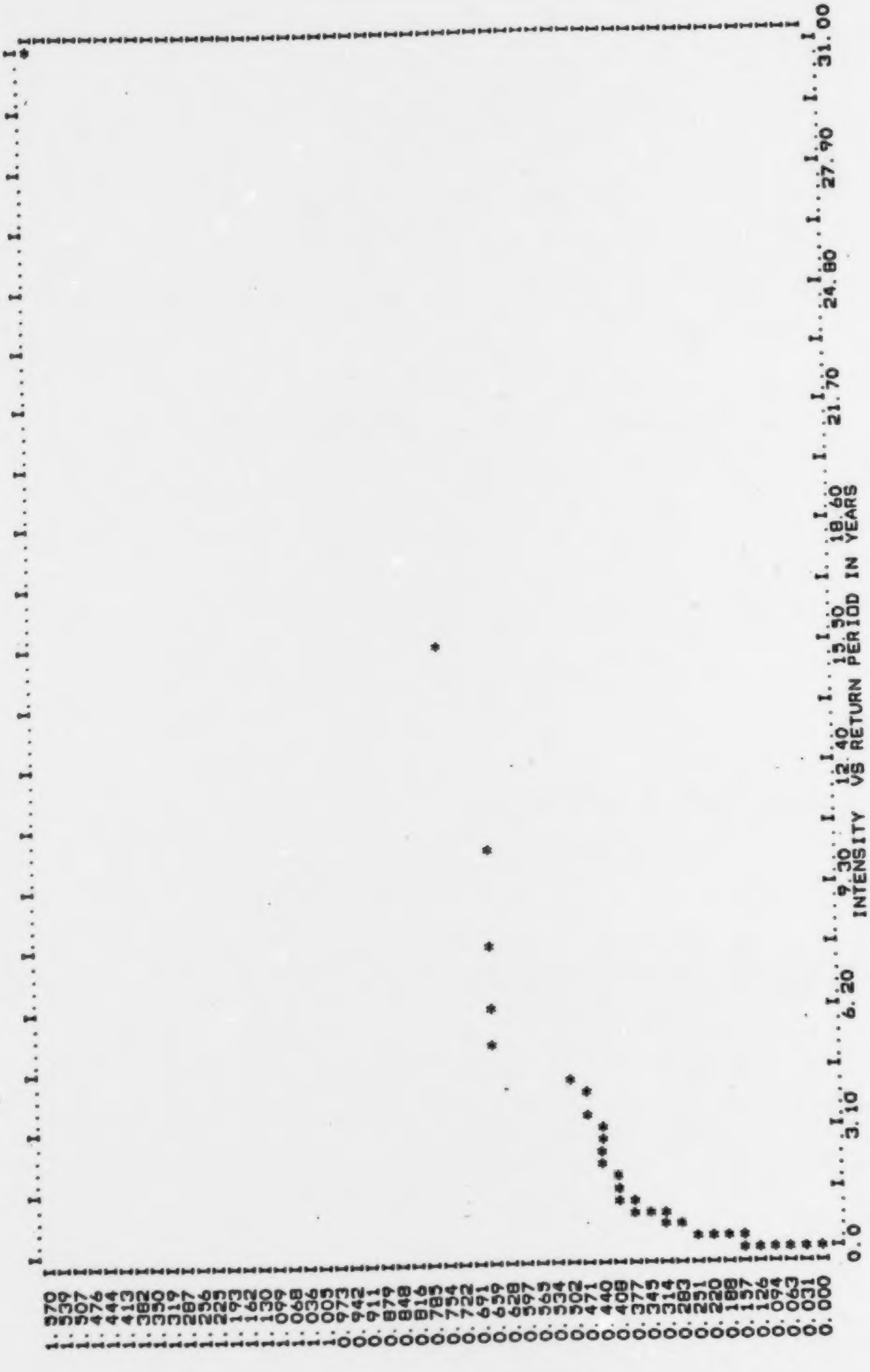
0.000

Figure II-28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0.722
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0.440
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0.377
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0.251
0.220
0.188
0.157
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0.094
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0.031
0.000
0.0
3.10
6.20
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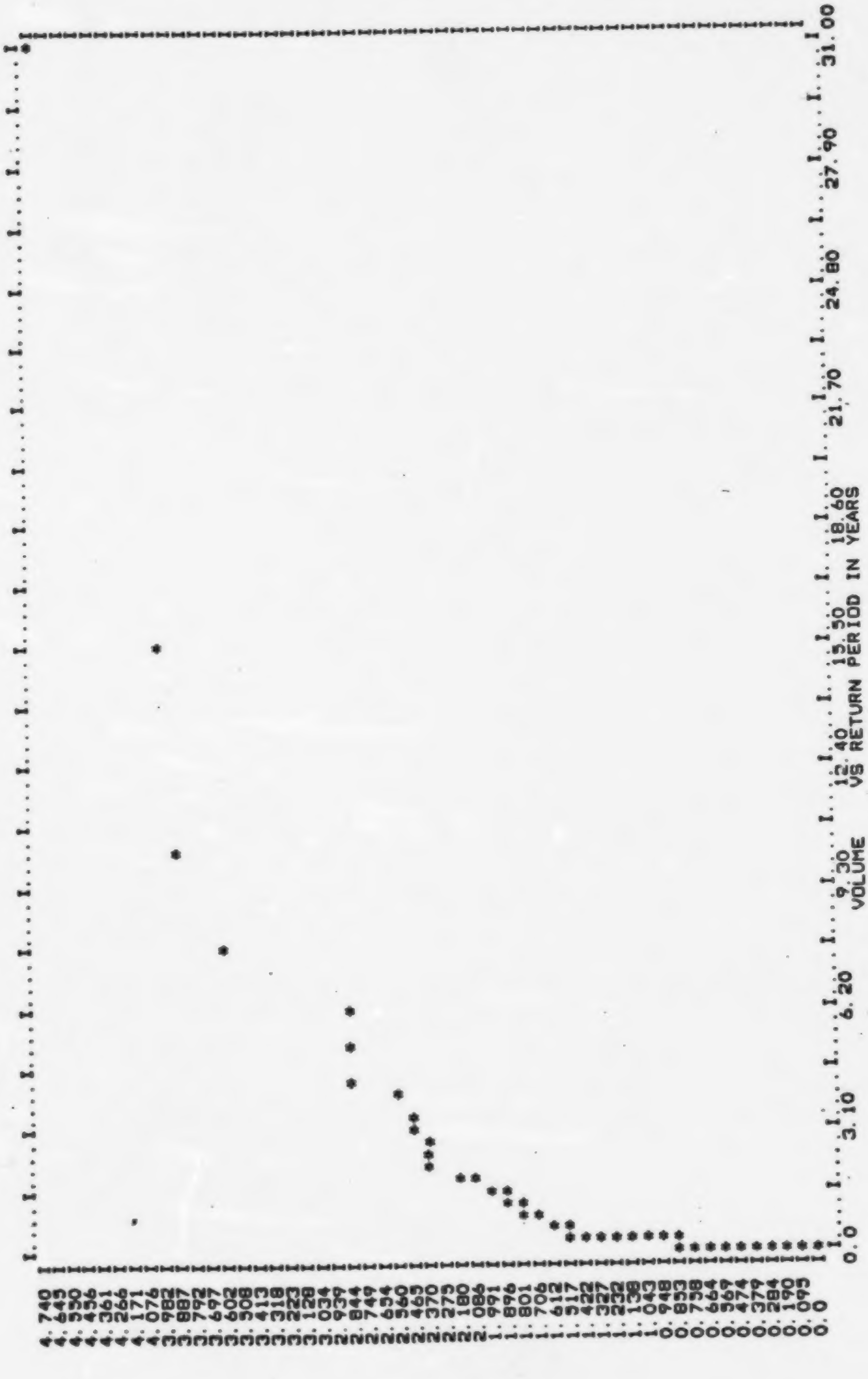
21.70
24.80
27.90
31.00
INTENSITY VS RETURN PERIOD IN YEARS

Figure II-29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3.10
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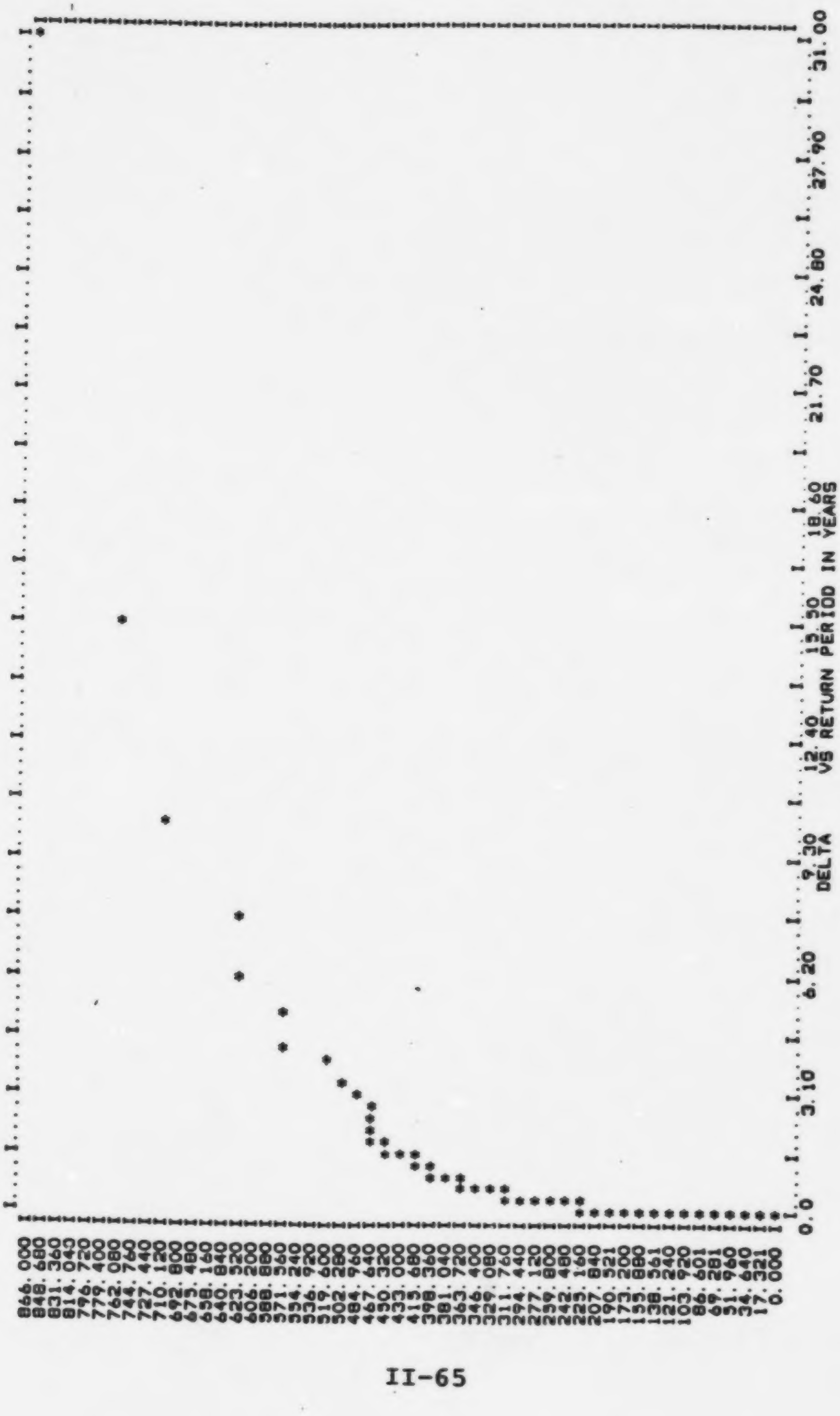
31.00
VOLUME VS RETURN PERIOD IN YEARS

Figure II-30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606.200
588.880
571.560
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467.640
450.320
433.000
415.680
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0.000
0.0
3.10
6.20
9.30
12.40
15.50
18.60
21.70
24.80
27.90
31.00
DELTA VS RETURN PERIOD IN YEARS

Figure II-31

REFERENCES

1. Southeast Michigan Council of Governments, Water Quality in Southeast Michigan: The Huron River Basin, Detroit, Michigan, 1978.

2. This description of the Huron River was adapted from Southeastern Michigan Water Resources Study, Technical Paper No. 6, Gazetteer of the Huron River Basin, U.S. Army Engineer District, Detroit, Corps of Engineers, 1969.

3. United States Department of Agriculture Soil Conservation Service, Soil Survey of Washtenaw County, Michigan, Ann Arbor, Michigan, 1977.

CHAPTER III. SAMPLING AND ANALYTICAL PROTOCOL

INTRODUCTION

This section of the report describes the equipment used for flow monitoring and water sampling, equipment problems and modifications, equipment installation procedures, sampling station descriptions, water sampling methodology and analytical protocol. It is felt that a section of this type is extremely useful to future project participants in that first hand knowledge of sampling equipment and sampling techniques obtained through field experience and trial and error can be transmitted. Hopefully some of these observations and suggestions will be beneficial in the planning and execution of future sampling programs.

EQUIPMENT DESCRIPTION

A. Samplers

The samplers used in this project are produced by Manning Environmental Corporation and are discrete (Model S-4040) and composite (Model S-3000) portable samplers. Both series (S-4040, S-3000) collect and store samples of liquids for subsequent analyses in selected volumes from 25 ml to 500 ml. The units self-purge before and after each sampling action to clear the intake tube of obstructions and residue from the previous sample. A powerful vacuum system is used to collect the sample. Samples can be collected on a flow proportional basis or on a time interval basis. The units consist of three major sub-assemblies: the top, the measuring assembly, and the lower case containing twenty-four 500 ml (or 1000 ml with minor modifications) polypropylene autoclavable bottles (discrete) or one 15 liter polyethylene bottle (composite). Power for the unit is supplied by a 12-volt automobile battery. (Figure III-1).

A Sigmamotor discrete sampler (Model WM-6-24) was used as a backup unit. The sampler has a fixed flow rate with variable pumping and cycle times. A peristaltic pump is used to draw the water sample up the sample line and into the sample bottle.

At most of the stations the samplers were activated by means of a float switch assembly. This assembly was built in house and is illustrated in Figure III-2. Float Switch Assembly Diagram

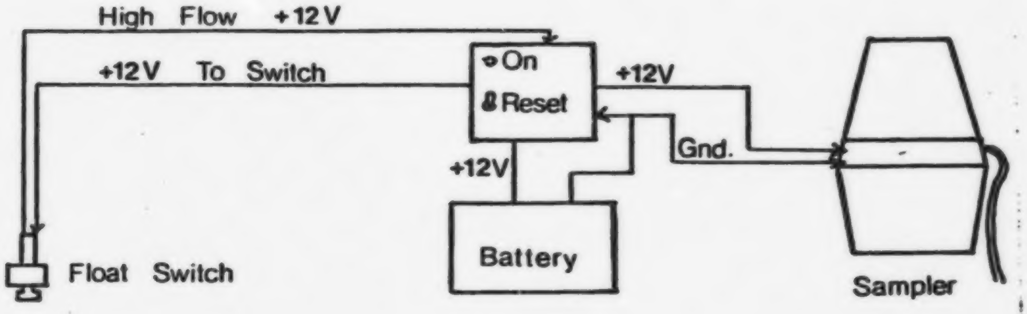


Figure III-2

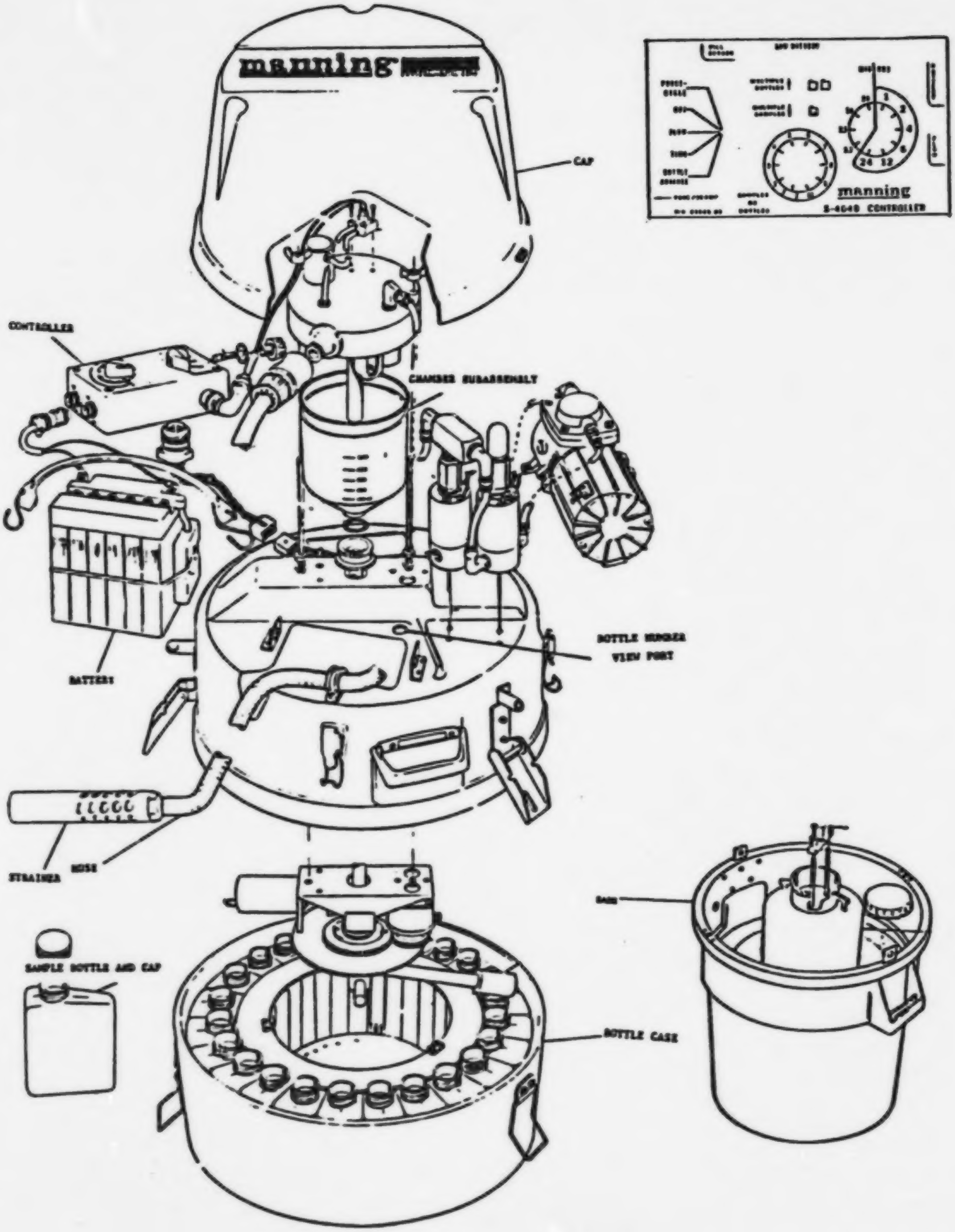

manning
CAP
manning
S-4040 CONTROLLER
1
2
4
6
24
12
CONTROLLER
CHAMBER SUBASSEMBLY
BOTTLE NUMBER
VIEW PORT
BATTERY
STRAINER
HOSE
SAMPLE BOTTLE AND CAP
BASE
BOTTLE CASE

Figure III - 1 Manning Water Sampler

The relay box is based on a double position double throw Potter and Brumfield relay. It uses one set of contacts to power up the sampler and one set of contacts to disconnect the power to the relay via the float switch. The input and output are bypassed to ground to prevent the contacts from burning up. A light emitting diode indicates the box has been activated. A single position single throw switch resets the unit.

The float switch is distributed by the Fluid Product Company. It is a level sensor that is capable of being set either in a normally open or normally closed position by rotating the float. The actual switch is a magnetic reed (with the magnet in the float). The float switch is mounted into a fiberglass electrical box with a handmade aluminum front. This unit is then mounted at base flow level. Any rise in baseflow will turn the sampler on. The unit requires regular maintenance due to the fact that during high flow dirt can get into the box and cause the switch to stick.

B. Flow/Level Recorders

Stevens Recorder Type F - Model 68

A Stevens Recorder Type F - Model 68 was used to measure changes in water level at most of the monitoring stations. The recorder measures changes in water level by means of a horizontal chart drum which is turned through float action proportional to changes in water levels. A stylus is moved to the right across the width of the chart at a constant speed controlled by the clock mechanism and with the combined movement of the chart drum and stylus a graphic record of water levels against time is produced. Flows can then be determined using stage-discharge curves. Four day clock gears were used to provide good resolution at 30 minute intervals. In addition, appropriate chart drum gears were used to provide enough resolution to detect .1-.2 inch changes in water level. The unit is illustrated in Figure III-3.

The flow recorders used in this study are produced by Manning Environmental Corporation and are the UF 1100 ultrasonic flow recorder and the F3000 A dipper flow recorder. The dipper unit measures level with an insulated electrical cable that dips into the water and retracts upon contact. This cycle is performed at five second intervals, each time providing level input. The ultrasonic unit has a transducer that transmits an ultrasonic pulse to the water and measures level by timing the return of the signal. The units utilize a program module that allows incorporation of standard equations for flow over or through a defined structure and provides data on a chart as percent of maximum flow rather than water level. For this reason, the option to obtain flow proportional samples collected at prescribed intervals of flow can be achieved when the flow recorder is linked to the sampler. Total flow is

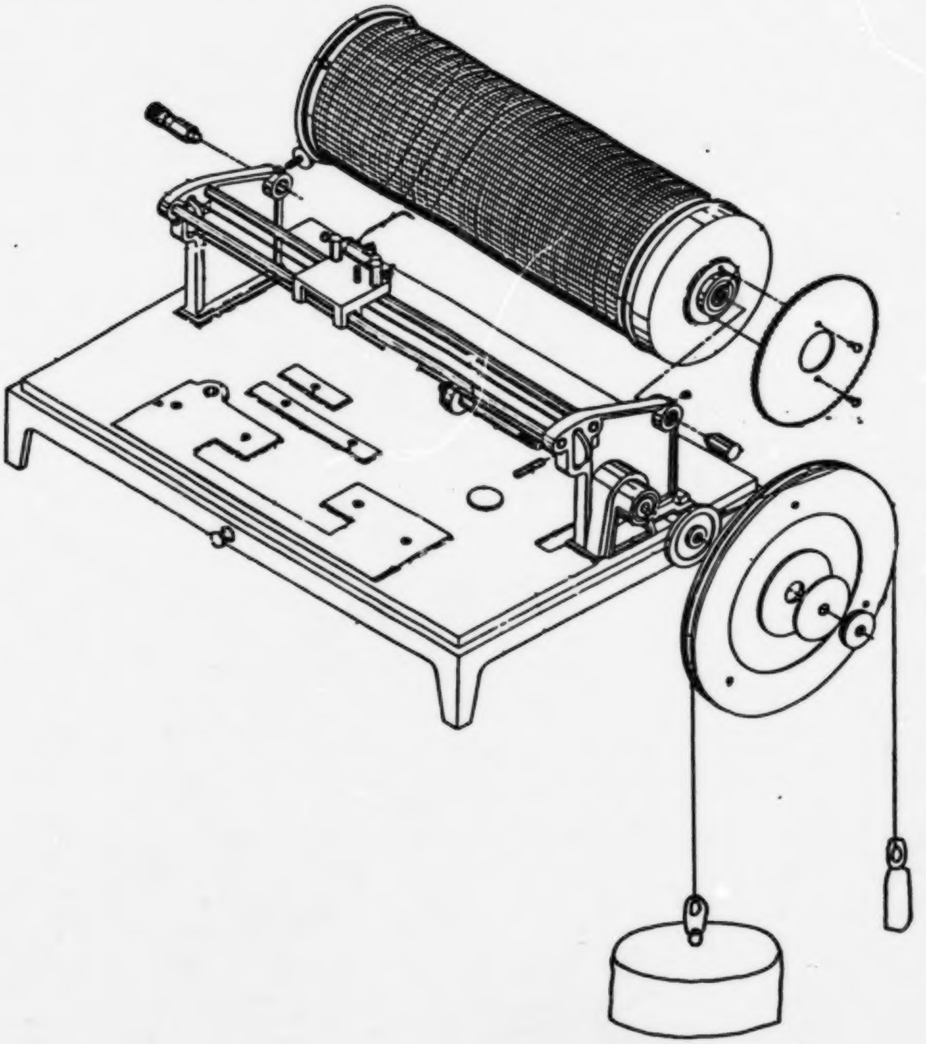


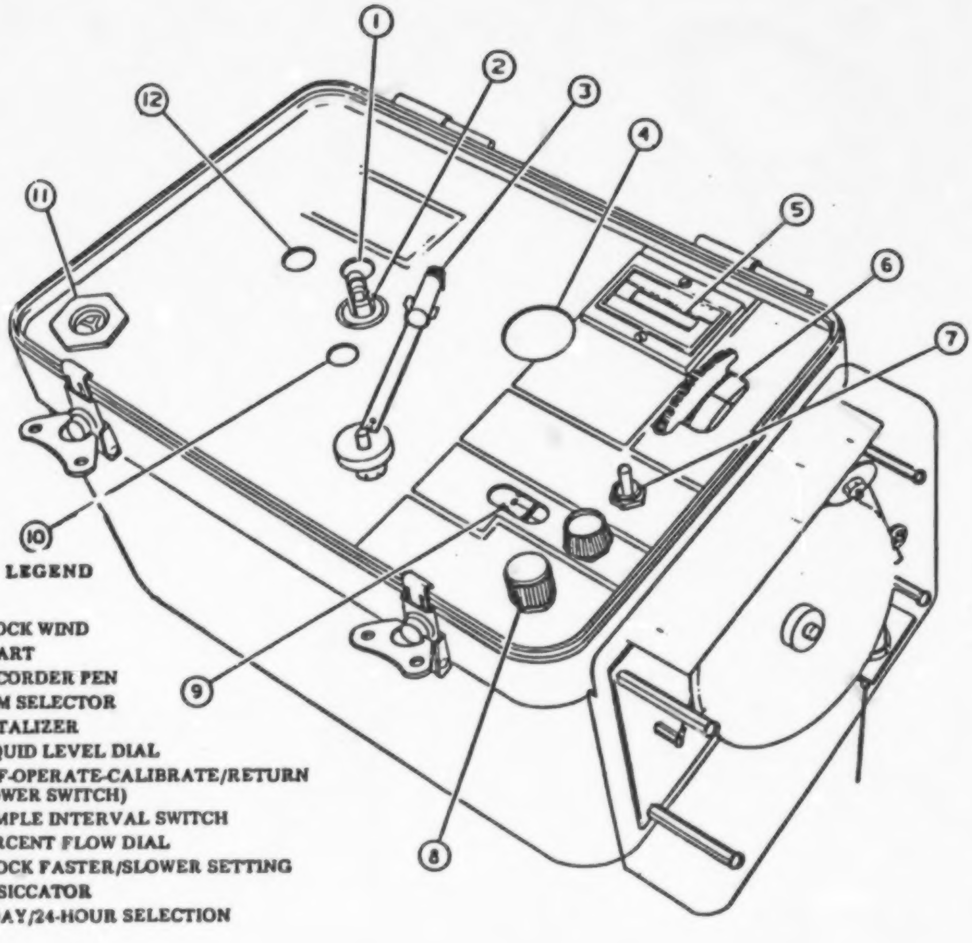
Figure III - 3 Stevens Level Recorder

provided by means of a digital totalizer. Chart operation is mechanically set for 24 hours or 7 day operation. The dipper unit is illustrated in Figure III-4. The recorders are powered by an external 12 volt automobile battery. The only modifications made to the units was the addition of large amounts of dessicant in (1 1/2 x 8") perforated PVC tubes in the bottom of the housings. This was found to be necessary to protect the units from moisture problems associated with the sample station environments.

C. Water Velocity Meter

Water velocity measurements were made using a Marsh-McBirney Model 201 Portable Water Current Meter. The instrument measures flow velocities up to 10 feet per second. It has three full scale ranges: 2.5, 5, and 10 feet per second, any of which can be selected by a rotating switch on the front panel. The accuracy of the instrument is based upon three factors:

1. Long term zero drift which is less than ± 0.07 ft/sec.
2. Linearity of response which is ± 2% of reading.
3. Absolute calibration which is ± 2% of reading.



LEGEND

1. CLOCK WIND
2. CHART
3. RECORDER PEN
4. CAM SELECTOR
5. TOTALIZER
6. LIQUID LEVEL DIAL
7. OFF-OPERATE-CALIBRATE/RETURN (POWER SWITCH)
8. SAMPLE INTERVAL SWITCH
9. PERCENT FLOW DIAL
10. CLOCK FASTER/SLOWER SETTING
11. DESICCATOR
12. 7-DAY/24-HOUR SELECTION

Figure III - 4 Manning Dipper Flow Recorder

D. Atmospheric/Precipitation

Rainfall intensity and level were measured by the use of a 7-day recording weighing-type gauge that measures the amount and intensity of rainfall by the accumulating weight of rainfall collected over time. The model used is manufactured by the Belfort Instrument Company (Cat. No. 5-780 Series), built to meet the standards of the National Weather Service (Figure III-5). Accuracy for the gauge (set at 12 inch capacity) according to manufacturers information booklet is 0.05% full scale within a temperature range of -40°F to +125°F. In addition, manual rain gauges were used throughout the study area to measure total rain volume.

Wetfall was collected by using two 11 1/2 inch polyethylene funnels drawing into 2-2 liter polyethylene bottles housed in a portable structure. This device was built in-house.

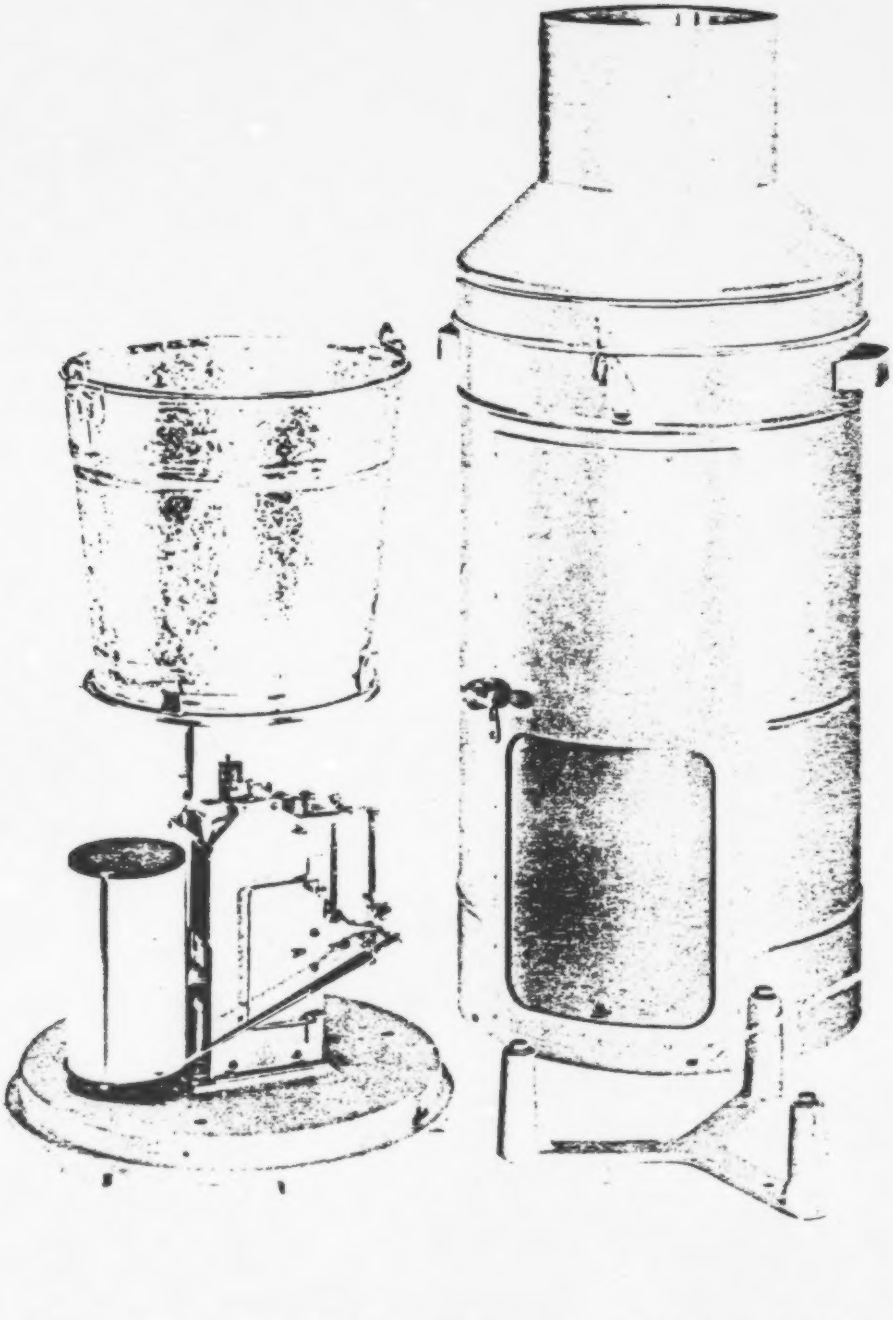


Figure III - 5 Belfort Instrument - Recording Rain Guage

WATER QUALITY SAMPLING PROGRAM

A. General

The selection of water quality sampling stations and water quality analyses to be performed was based on the objectives of monitoring the inputs of the various drains to the Huron River, determination of water quality in the river during and following storm discharges, and the measurement of water quality conditions into and out of the various BMP's under investigation. Five stations for the measurement of flow and collection of composite water samples were established at the outlets of each of the five drainage districts discharging into the Geddes Pond Area of the Huron River. In addition, two stations were established on the river itself one upstream of the drains at Argo Dam and one downstream at Geddes Dam. Water quality monitoring stations were also established on the two inlet tributaries to the Pittsfield-Ann Arbor retention basin, on the outlet from the basin, on the inlet and outlet of the Swift Run Wetlands and on the inlet and outlet of the Traver Creek Retention Basin BMP's. The locations of all of these sampling stations are illustrated in Figure III-6.

B. Station Description - River and Drain Outlet Stations

Sampling stations were established at the outlets of each of the five main drains entering Geddes Pond (Spring 1979). The stations were located as near the

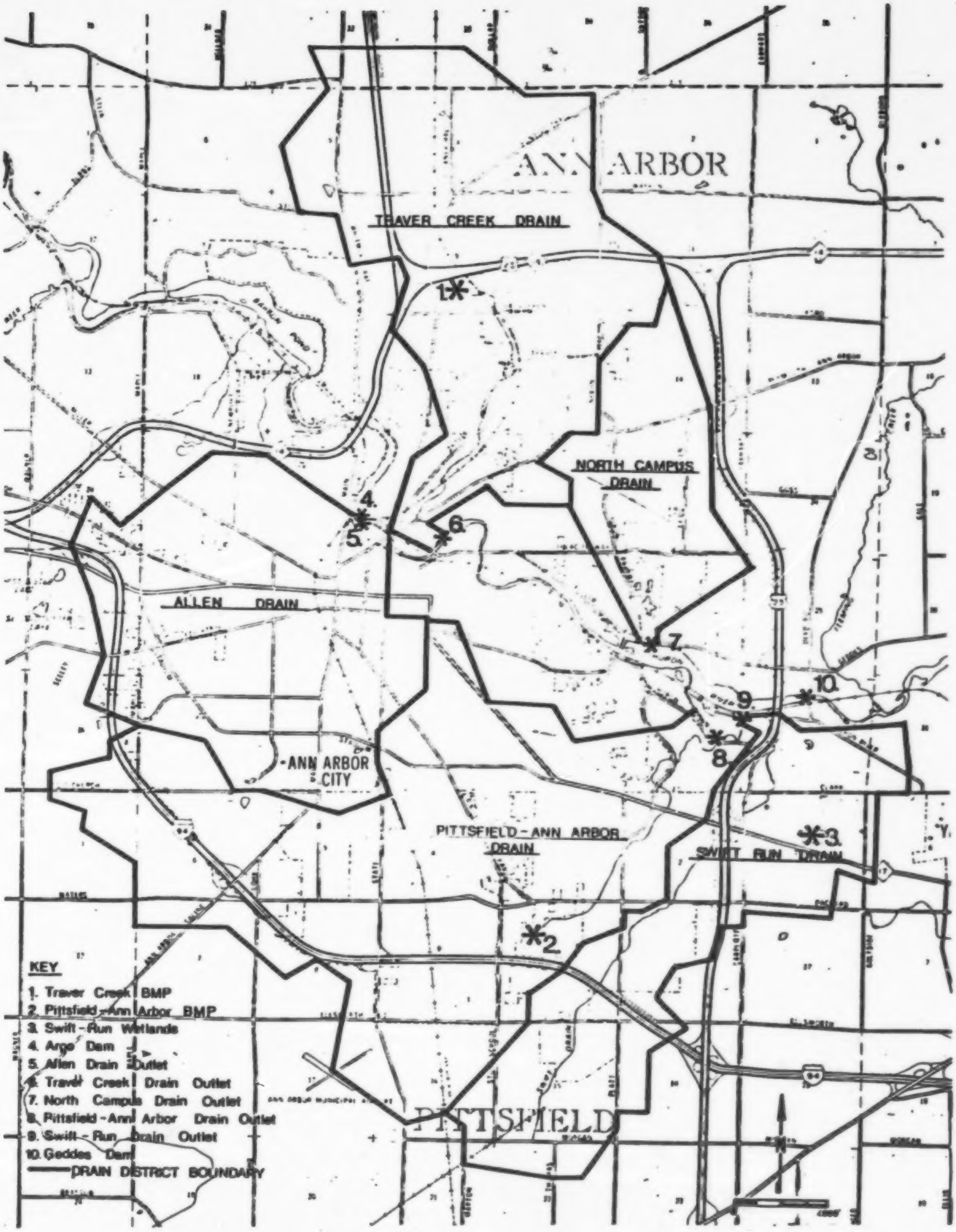

ANN ARBOR
TRAVER CREEK DRAIN
NORTH CAMPUS DRAIN
ALLEN DRAIN
ANN ARBOR CITY
PITTSFIELD - ANN ARBOR DRAIN
SWIFT RUN DRAIN
PITTSFIELD
1
2
3
4
5
6
7
8
9
10
KEY
1. Traver Creek BMP
2. Pittsfield - Ann Arbor BMP
3. Swift - Run Wetlands
4. Argo Dam
5. Allen Drain Outlet
6. Traver Creek Drain Outlet
7. North Campus Drain Outlet
8. Pittsfield - Ann Arbor Drain Outlet
9. Swift - Run Drain Outlet
10. Geddes Dam
DRAIN DISTRICT BOUNDARY

Figure III-6. Sampling Stations

mouth of the drain as possible without being influenced by backwater effects. This was possible for all drain outlets except Allen Drain where the low flow was affected by the cycling of Argo Dam. A rating curve was established to account for this problem and at higher flows during a storm the backwater effects were negligible. Each station consisted of a continuous level recorder and a Manning automatic sampler for taking discrete samples. Equipment was housed in steel boxes for security. Float switches were used to activate the sampling equipment. All of the drains were open drains with the exception of Allen Drain which is an enclosed system. In each case the flow monitoring station was established at a bridge or culvert so that a predictable cross sectional area was available.

The sampling stations for the river were established at Argo and Geddes Dam. Automatic sampling equipment was placed on the dam structure and samples were collected where the water passed through the dams. Level recording equipment measured water elevation changes which were utilized in conjunction with design rating curves to determine flow. A U.S.G.S. monitoring station is located just downstream of Argo Dam to serve as a check on the flow data.

C. Station Description - Pittsfield-Ann Arbor Retention Basin

Monitoring of the Pittsfield-Ann Arbor Retention Basin consisted of the determination of flow and pollutant levels at two inlet tributary stations (North and South Arm) and one outlet station. A Steven's level recorder and Manning automatic water sampler capable of taking 24 discrete samples were located at each station. The South Arm tributary station was located on a roadway bridge (Birch Hollow Drive). Sampling equipment was protected in a steel utility box with conduit on the outside to protect the sampler line. The level recorder was housed in a small steel box next to the sampler box and placed over the steel pipe stilling well. Sampling equipment at the North Arm and Outlet stations were housed in steel drums and level measuring devices housed in steel boxes over stilling wells to minimize vandalism. Conduit was used to protect the sampling lines. The water quality sampling equipment was activated by a float switch set to commence sampling when water depth rose a predetermined amount. Stage discharge curves were established for each of three stations. Stations were established during the Summer of 1979, deactivated during the winter and reactivated for the 1980 sampling season. A new stage discharge curve was established at each station when the stations were reactivated to reflect any changes that might have occurred in the stream bed or drainage pipe.

D. Station Description - Swift Run Wetlands

Two stations were installed at the wetlands. The inlet station located at the upstream side of the I-94 culvert consisted of a stilling well and Stevens level recorder for flow monitoring along with an automatic water sampler housed in a steel drum and set on a concrete pad. The sampler was equipped with a float switch-relay activation system. The outlet station located at the newly constructed wetlands outlet structure (1980) consisted of a free standing stilling well with a steel security box attached to the top. A Manning dipper recorder was housed in the box to provide flow information. The automatic sampler was housed in a steel security box with the sample line housed in a conduit for protection. An inter-connect cord between the dipper and sampler allowed for the automatic collection of flow proportioned samples. Stage-discharge curves were established for the stations.

E. Station Descripton - Traver Creek Retention Basin

Monitoring stations at the inlet and outlet of the Traver Creek Retention Basin were established in the Spring of 1981. Due to construction delays in building the by-pass structure, the retention basin acted as an online retention basin during the study period. The by-pass structure was finished during the end of the Summer of 1981. Construction activities on the by-pass structure did not occur until after the completion of the monitoring program. The sampling stations were similar to other stations used in the project with Stevens level recorders being used to record water depth and Manning samplers being used for sample collection. Steel boxes were used to house the equipment. Stage-discharge curves were established for these stations.

Figure III-7 illustrates an equipment installation that was typical at most of the monitoring stations. However, specific site characteristics dictated the final monitoring station design.

F. Rainfall Stations

During the 1979 sampling year one continuous recording rain gauge and three manual gauges were used to monitor rainfall. The recording gauge is located at the University of Michigan weather station on North Campus. This gauge is located on the border of the North Campus Drain and the Traver Creek Drain. One manual gauge was also located in the border area of the North Campus and Traver Creek Drains. In addition, a manual gauge was located in the Allen Drain district and the third manual gauge was located in the Pittsfield-Ann Arbor Drain area and adjacent to the Swift Run Drain.

A second continuous recording gauge was installed in place of the manual gauge in the Pittsfield-Ann

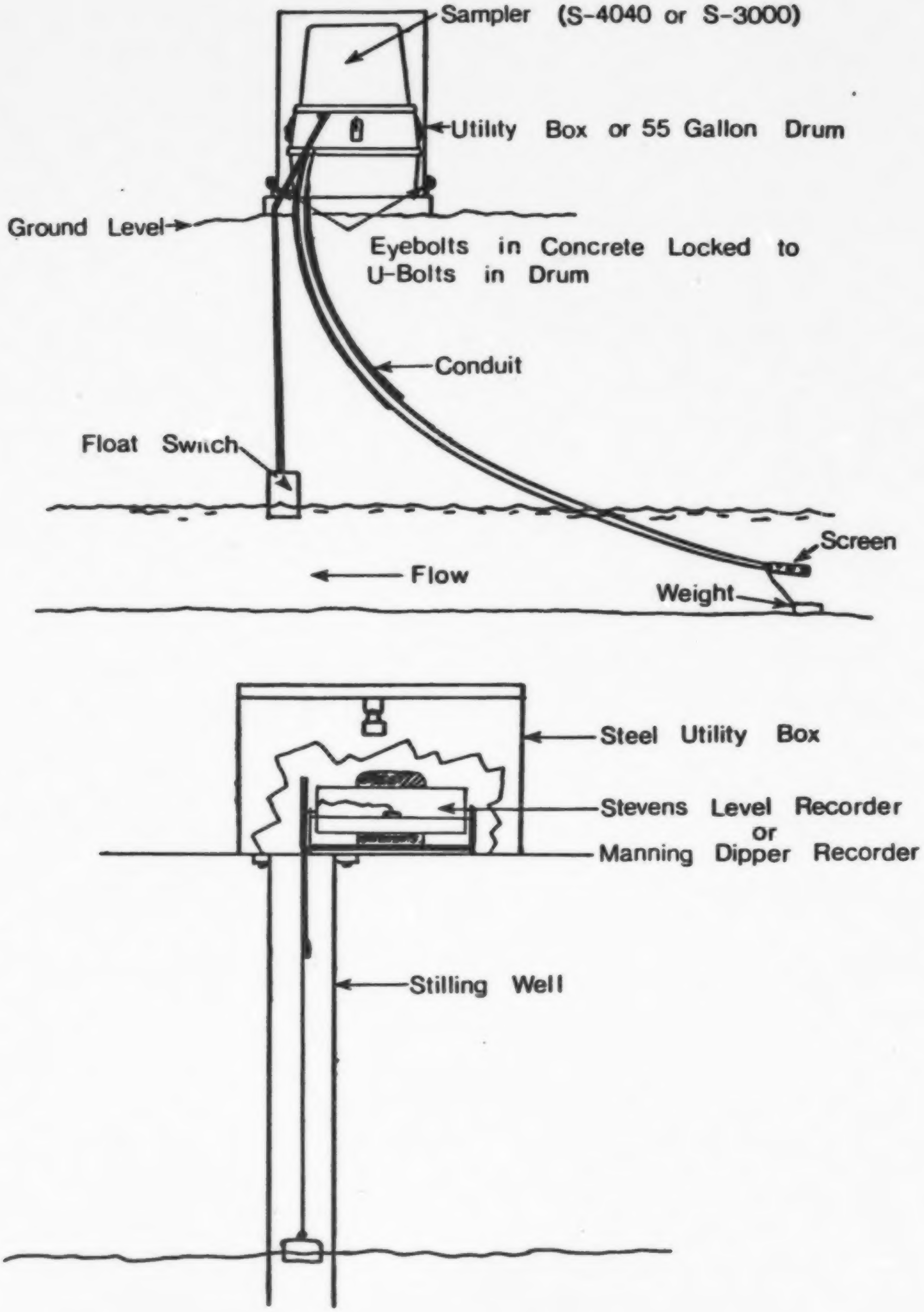

Sampler (S-4040 or S-3000)
Utility Box or 55 Gallon Drum
Ground Level
Eyebolts in Concrete Locked to U-Bolts in Drum
Conduit
Float Switch
Screen
Flow
Weight
Steel Utility Box
Stevens Level Recorder or Manning Dipper Recorder
Stilling Well

Figure III-7 Equipment Installation

Arbor basin at the beginning of the 1980 monitoring season. This gauge allowed for the direct collection of rainfall intensity data in the Pittsfield-Ann Arbor retention basin and Swift Run wetland area. During the winter months the unit was set up to measure snowfall in inches of water. Following the end of the snow period the unit was converted back to rainfall measurement operation. The unit was moved at the end of April 1981 to the new ENCOTEC office facility at 3965 Research Park Drive. This location was approximately 0.2 miles from the previous location. The recording rain gauge was still adjacent to the Swift Run Drainage District, and approximately 10 miles from the Traver Creek Basin. The U of M gauge was located immediately adjacent to the Traver Basin. A manual gauge was also installed at the outlet of the Traver Creek Retention Basin to provide better rainfall data for that area.

The automated weighing-type gauge setup located at 3965 Research Park Drive meets the NURP placement characteristics needed to receive a "fair to good" rating. The only criterion it does not meet as specified in the NURP Data Management Procedures Manual in order to receive a good rating is it is located on top of a building for security reasons. The manual gauge used throughout the district are rated as "fair" in that they adhere to most of the placement guidelines specified in the Data Management Procedures Manual.

G. Sampling Protocol

Water quality samples were collected using the automatic sampling equipment on a time basis. Discrete samples were collected at fifteen or thirty minute time intervals. One exception to this, however, was the Swift Run Wetlands Outlet where a Manning flow recorder automatically pulsed the sampler for a flow proportionate sample. Flow data, obtained from the continuous level recorders, was then used to composite the discrete samples on a flow proportionate basis. Generally, for the rainfall events, one to two composites were made to represent the major runoff portion of the event, and one or two additional composites were made to represent the tail portion of the curve and background conditions. Thus, a series of sequential composite samples were obtained to represent each runoff event.

The flow data for the drains was obtained from the level recorders through the use of a developed stage discharge curve. The curve was based on a series of depth and velocity measurement taken over a range of flow during dry and wet weather periods. Water depths were manually read from the recorder charts and plotted or charted as flow-time relationships for each event. Flow rates for the Huron River were obtained by monitoring water level at each dam. Rating curves for the dams were provided by the engineering design firm. A U.S.G.S. gauging station is also located between Argo and Geddes Dam. This station provided a cross check in the river flow data.

Samples which were composited, were either analyzed immediately by the laboratory or preserved by approved U.S.E.P.A. procedures. All compositing and preservation was performed in the laboratory as all stations were in close proximity to the offices.

H. Analytical Protocol

The complete analytical program for this project is shown in Table III-1. All analytical procedures followed approved methods.

TABLE III-1. MONITORED CHEMICAL PARAMETERS

Primary Analysis

Total Suspended Solids
Total Dissolved Solids
Particle Size Distribution
pH/Alkalinity
Nitrate Nitrogen
Total Kjeldahl Nitrogen
Soluble Kjeldahl Nitrogen
Total Phosphorus
Soluble Phosphorus
Chemical Oxygen Demand
Biochemical Oxygen Deman
Total Iron
Soluble Iron
Total Lead
Soluble Lead

Periodic Sample Analysis

Grease and Oil
Total Cadmium
Total Zinc
Total Chromium
Total Nickel
Fecal Coliform
Fecal Streptococcus

To ensure the reliability of the data base, a site specific quality assurance program was developed in addition to standard quality assurance procedures. Both field and laboratory procedures are incorporated in the quality assurance program which is presented in the Appendix of Volume I.

CHAPTER IV. BMP EVALUATION

PITTSFIELD-ANN ARBOR RETENTION BASIN

Introduction

The retention basin on the Pittsfield-Ann Arbor drain was described earlier in this report. This basin was designed to provide flood relief for downstream areas by reducing peak flows during flooding. The initial design of this basin was not based on improving water quality in urban runoff, although most retention ponds do show some buildup of silt over time due to sedimentation. The basin has a long aproach channel on the inlet side which receives flow from two tributary areas referred to in this report as the north arm and south arm inlets. The outlet is located on the opposite end of the pond which should provide a reasonable flow path over which sedimentation can occur and minimize short circuiting problems. Thus, the general basin geometry would appear to favor the sedimentation process. The design of the outlet weir is considered less than ideal in two ways. The bottom of the pond has been sloped from a midpoint depth to each side including the outlet side. Consequently, the bottom of the pond is only approximately two to three feet below most points of the outlet overflow structure. This creates the potential for scour of some materials near the outlet during high flow conditions. The second point is the length of the overflow structure. There is sixty feet of overflow length including the front and sides of the weir. This length results in very high hydraulic loadings per length of overflow weir during high flow periods. Given the positive and negative aspects of the basin, overall it is a typical retention basin designed for flood relief. The objective of the evaluation of this basin is to determine the level of water quality improvement which can be expected from such a basin and possibly identify areas where changes in future basin design will enhance the water quality benefits which can be gained from this type of basin.

Data Collection

As described earlier in this report, monitoring of the Pittsfield-Ann Arbor Retention Basin consisted of the determination of flow and pollutant levels at two inlet tributary stations (North and South Arm) and one outlet station. Steven's level recorders were used in conjunction with site specific stage discharge curves to determine flows, and Manning discrete automatic water samplers equipped with float switch activation assemblies were used to collect water samples on a time basis. Depending on the forecasted storm size and duration the samplers were set up to collect 500-1000 ml samples every fifteen or thirty minutes. Samples were collected throughout the runoff period. Flow data, obtained from the continuous level recorders, was then used to composite the discrete samples on a flow proportionate basis. Generally, for the rainfall events, one to two composites were made to represent the major runoff portion of the event and one or two additional samples were composited to represent the tail portion of the curve and background conditions. Thus, a series of sequential composite samples were obtained to represent each runoff event. During the snow melt event grab samples were taken at predetermined times throughout the elevated runoff period. Flows were determined using stage-discharge curves and depth measurements taken at the time of the grab sample collection.

Samples which were composited, were either analyzed immediately by the laboratory or preserved by approved USEPA procedures. All compositing and preservation was performed in the laboratory as all stations were in close proximity to the offices. Analytical procedures followed approved methods. Quality control and quality assurance procedures are presented in Appendix I.

Results

Six rain events and one snow melt event were monitored over a three year period. Summaries of the pollutant loadings entering and leaving the basin are presented in Tables IV-1-7. These summary tables are based on total loadings entering and leaving the basin during the runoff period. The loadings presented include both baseflow conditions and loadings from the storm runoff period. Individual parameter values for each composite are presented in a separate data document. Generally, the first composite sample represents the beginning period of runoff, the second sample the middle portion of the storm, the third sample the tail portion of the curve, and subsequent samples represent baseflow conditions. Sampling at the outlet station was continued for several days following a storm to insure water entering during the storm had passed through the basin. These composite cutoff times are only estimates and the actual composite cutoffs depend on the storm and runoff characteristics for each event.

TABLE IV-1

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

June - July, 1979

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
South Arm Inlet	1,730,000	42,000	5,400	<273	46	100	83	14	2.3
North Arm Inlet	2,200,000	35,000	18,000	<367	83	162	77	35	4.8
Total	3,930,000	77,000	23,400	<640	129	262	160	49	7.1
Retention Basin Outlet	3,930,000	72,000	13,000	<496	122	258	155	36	7.6
Pollutant Removed		5,000	10,400		7	4	5	13	(-0.5)
Percent of Inlet Retained		x	44		x	x	x	27	x

x = 0±10%

TABLE IV-1 (Continued)

Summary of Metal Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

June - July, 1979

	Flow Volume Cu ft.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Total Copper lbs.	Total Nickel lbs.
South Arm Inlet	1,730,000	144	6.2	1.0	<0.11	14	4.8	0.04	0.5	0.21
North Arm Inlet	2,200,000	395	15	15	<0.15	25	3.2	0.15	1.8	0.79
Total	3,930,000	539	21.2	16	<0.26	39	8.0	0.19	2.3	1.00
Retention Basin Outlet	3,930,000	502	23	8.3	<0.25	33	6	0.13	0.8	0.46
Metals Removed		37	(-1.8)	7.7		6	2	0.06	1.5	0.54
Percent of Inlet Retained		x	x	48		15	25	32	65	54

x = 0±10%

TABLE IV-2

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

October, 1979

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	5-day Biological Oxygen Demand lbs.	Total Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Total Lead lbs.	Total Iron lbs.
South Arm Inlet	369,000	13,000	520	82	11	1.0	0.08	17
North Arm Inlet	162,000	4,900	720	120	14	5.0	<0.68	26
TOTAL	531,000	17,900	1,240	202	25	6.0	<.76	43
Outlet	597,000	13,200	1,100	190	31	2.7	0.30	32
Pollutant Removed		4,700	140	12	(-6)	3.3	<.46	9
Percent of Inlet Removed		26	11	x	(-24)	55	<60	21
Base Flow Loads (using background concentrations) not included in following balance.								
Inlet	---	---	924	113	16	5.1	0.73	29
Outlet	---	---	504	41	16	1.2	0.23	17
Pollutant Removed	---	---	420	72	0	3.9	0.50	12
Percent of Inlet Removed	---	---	45	64	x	76	68	41

x = 0±10%

TABLE IV-2 (Continued)

Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

October, 1979

	Flow Volume Cu ft.	Soluble Iron lbs.	Soluble Phosphorus lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Total Copper lbs.	Total Nickel lbs.
South Arm Inlet	369,000	1.5	<0.24	0.03	0.6	0.26	<0.003	<0.03	0.07
North Arm Inlet	162,000	<2.2	<0.61	<0.08	0.9	0.15	<0.003	<0.20	0.07
TOTAL	531,000	<3.7	<0.85	<0.11	1.5	0.41	<0.006	<0.23	0.14
Retention Basin Outlet	579,000	2.5	<.37	<0.04	1.2	0.33	<0.027	<0.09	0.17
Pollutant Removed		<1.2		<0.07	0.3	0.08			(-0.03)
Percent of Inlet Retained		<32		<64	20	20			(-21)

TABLE IV-3

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

August 10-11, 1980

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
South Arm Inlet	321,000	9,200	800	7,000	100	2.6	15.0	7.4	1.4	<0.20
North Arm Inlet	338,000	4,200	1,000	4,000	84	11.0	23.0	9.3	3.4	0.84
Total	659,000	13,400	1,800	11,000	184	13.6	38.0	16.7	4.8	<1.04
Retention Basin Outlet	664,000	17,200	1,099	13,500	155	13.9	37.8	20.3	4.9	0.42
Pollutant Removed		(-3,800)	701	(-2,500)	29	(-0.3)	0.2	(-3.6)	(-0.1)	<0.62
Percent of Inlet Retained		(-28)	39	(-23)	16	x	x	(-22)	x	60

x = 0±10%

TABLE IV-3 (Continued)

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

August 10-11, 1980

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
South Arm Inlet	321,000	560	20	0.18	0.20	<0.02	---	---	---	---
North Arm Inlet	338,000	886	23	1.10	0.87	0.04	---	---	---	---
Total	659,000	1,446	43	1.28	1.07	<0.06	---	---	---	---
Retention Basin Outlet	664,000	1,022	41	0.66	0.7	<0.04	---	---	---	---
Pollutant Removed		424	2	0.62	0.36	<0.02	---	---	---	---
Percent of Inlet Retained		29	x	48	34	33	---	---	---	---

x = 0±10%
-- = parameter not monitored during this event

TABLE IV-4

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

September 9-11, 1980

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
South Arm Inlet	1,716,000	51,200	5,060	13,200	909	26.2	113	52.2	14.00	<1.2
North Arm Inlet	574,000	20,500	2,319	5,800	114.5	12.4	36.8	19.8	6.68	0.89
Total	2,290,000	71,700	7,379	19,000	1,024	38.6	149.8	72.0	20.68	<2.09
Retention Basin Outlet	2,286,000	55,600	6,660	20,500	544	46.4	135.0	75.0	18.4	<4.87
Pollutant Removed		16,100	719	(-1,500)	480	(-7.8)	14.8	(-3)	2.28	
Percent of Inlet Retained		22	10	x	47	(-20)	10	x	11	

x = 0±10%

TABLE IV-4 (Continued)

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

September 9-11, 1980

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
South Arm Inlet	1,716,000	3,480	170.3	1.41	<9.5	<0.10	7.12	6.11	0.023	201
North Arm Inlet	574,000	232	58.0	0.74	<1.5	<0.04	2.18	0.64	0.012	98
Total	2,290,000	3,712	228.3	2.15	<11	<0.14	9.30	6.75	0.035	299
Retention Basin Outlet	2,286,000	3,300	215.0	1.97	1.25	<0.15	6.90	0.77	<0.045	<487
Pollutant Removed		412	13.3	0.18	<9.75		2.40	5.98	(-0.01)	(-188)
Percent of Inlet Retained		11	x	x	>89		26	89	(-29)	(-63)

x = 0±10%

TABLE IV-5

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

September 17-19, 1980

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
South Arm Inlet	1,623,000	35,300	4,120	15,000	473	36.4	79.7	53.5	12.63	2.02
North Arm Inlet	1,084,000	18,700	2,986	10,400	236	32.9	69.4	32.6	10.60	2.08
Total	2,707,000	54,000	7,106	25,400	709	69.3	149.1	86.1	23.23	4.10
Retention Basin Outlet	2,746,000	52,600	5,900	22,300	625	73.0	113.0	76.0	21.80	4.3
Pollutant Removed		(-1,400)	1,206	3,100	84	(-3.7)	36.1	10.1	1.43	(-0.2)
Percent of Inlet Retained		x	17	12	12	x	24	12	x	x

x = 0±10%

TABLE IV-5 (Continued)

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

September 17-19, 1980

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
South Arm Inlet	1,623,000	2,760	118.2	3.21	0.56	<0.11	4.60	2.20	<0.039	149
North Arm Inlet	1,084,000	2,250	91.5	3.81	1.54	<0.06	3.60	0.32	<0.021	<67
Total	2,707,000	5,010	209.7	7.02	2.1	<0.17	8.20	2.52	<0.06	<216
Retention Basin Outlet	2,746,000	5,050	175.0	6.00	1.84	<0.18	6.53	0.60	<0.033	234
Pollutant Removed		(-40)	34.7	1.02	0.26		1.67	1.92		(-18)
Percent of Inlet Retained		x	17	14	12		20	76		x

x = 0±10%

TABLE IV-6

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

October 24-27, 1980

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
South Arm Inlet	401,000	12,240	1,692	5,820	187	7.9	26.3	15.7	2.7	0.31
North Arm Inlet	642,000	15,300	1,630	9,100	503	14.3	28.1	25.1	13.3	6.80
Total	1,043,000	27,540	3,322	14,920	690	22.2	54.4	40.8	16.0	7.10
Retention Basin Outlet	1,071,000	29,800	1,440	14,300	764	17.2	49.5	33.8	13.4	6.16
Pollutant Removed		(-2,260)	1,882	620	(-74)	5.0	4.9	7.0	2.6	.94
Percent of Inlet Retained		x	57	x	x	23	x	17	16	13

x = 0±10%

TABLE IV-6 (Continued)

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

October 24-27, 1980

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
South Arm Inlet	401,000	657	41.2	0.66	0.27	<0.03	---	---	---	---
North Arm Inlet	642,000	2,044	77.6	4.22	<1.90	<0.38	---	---	---	---
Total	1,043,000	2,701	118.8	4.88	<2.17	<0.41	---	---	---	---
Retention Basin Outlet	1,071,000	2,100	57.4	4.64	1.19	<0.24	---	---	---	---
Pollutant Removed		601	61.4	0.24	<0.98		---	---	---	---
Percent of Inlet Retained		22	52	x	45		---	---	---	---

x = 0±10%
-- = parameter not monitored during this survey

TABLE IV-7

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

February 17-19, 1981
SNOW MELT

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
South Arm Inlet	6,753,000	255,000	43,100	39,000	2,560	212	783	590	138	77
North Arm Inlet	5,615,000	110,900	31,700	26,400	1,827	245	474	331	80	37
Total	12,368,000	365,900	74,800	65,400	4,387	457	1,257	921	218	114
Retention Basin Outlet	11,523,000	323,000	54,300	58,800	3,870	494	1,119	767	274	100
Pollutant Removed		42,900	20,500	6,600	517	(-37)	138	154	(-56)	14
Percent of Inlet Retained		12	27	10	12	x	11	17	(-26)	12

x = 0±10%

TABLE IV-7 (Continued)

Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County, Michigan

February 17-19, 1981
SNOW MELT

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
South Arm Inlet	6,753,000	21,570	892	48	8.0	<0.60	38	---	---	1,257
North Arm Inlet	5,615,000	14,890	689	27	13.2	0.87	33	---	---	1,197
Total	12,368,000	36,460	1,581	75	21.2	1.47	71	---	---	2,454
Retention Basin Outlet	11,523,000	29,820	1,270	55	30	<1.17	68	---	---	2,340
Pollutant Removed		6,640	311	20	-8.8	<0.30	3	---	---	114
Percent of Inlet Retained		18	20	26	(-41)	<20	x	---	---	x

x = 0±10%
-- = parameter not monitored during this survey

Figures IV-1-7 show the runoff hydrographs for the three monitoring stations for each event. These hydrographs show quite clearly the difference in flow characteristics between the two inlet stations. The north arm, an enclosed system until the discharge at the retention basin entrance, is fairly flashy with high peaks and a quick return to baseflow conditions. The south arm, however, exhibits tempered peaks and a more broad hydrograph with a long tail curve. This runoff pattern reflects the open channel conditions plus the impact of the upstream retention basins at the main commercial areas. These upstream basins temper the flow consideraby as demonstrated during these monitored rainfall events.

Overall comparison of the flow data collected at the various stations during all of the events and dissolved solids data shows a fairly good mass balance agreement between the two inlets and outlet stations. Runoff coefficients for the stations are fairly constant for all of the events (Table IV-8).

Table IV-8.
Pittsfield-Ann Arbor Retention Basin
Runoff Coefficients

Date	North Inlet	South Inlet	Outlet
6/30/79	0.09	0.11	0.10
10/22/79	0.06	0.20	0.13
8/10/80	0.13	0.17	0.15
9/9/80	0.06	0.26	0.14
9/17/80	0.15	0.33	0.23
10/24/80	0.14	0.12	0.13

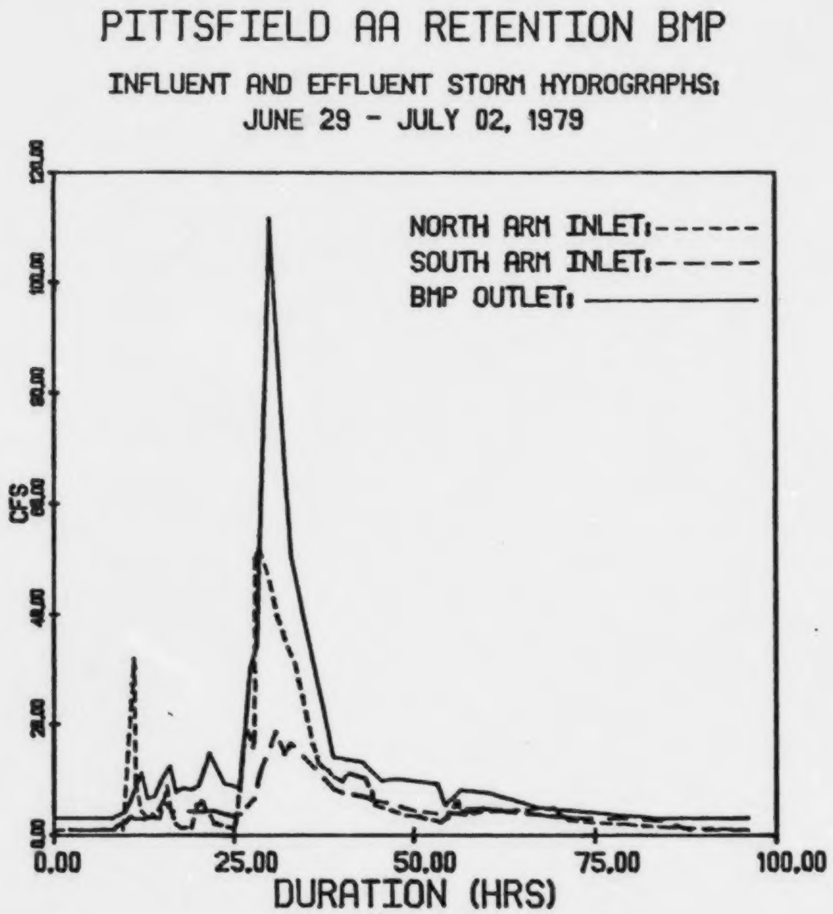
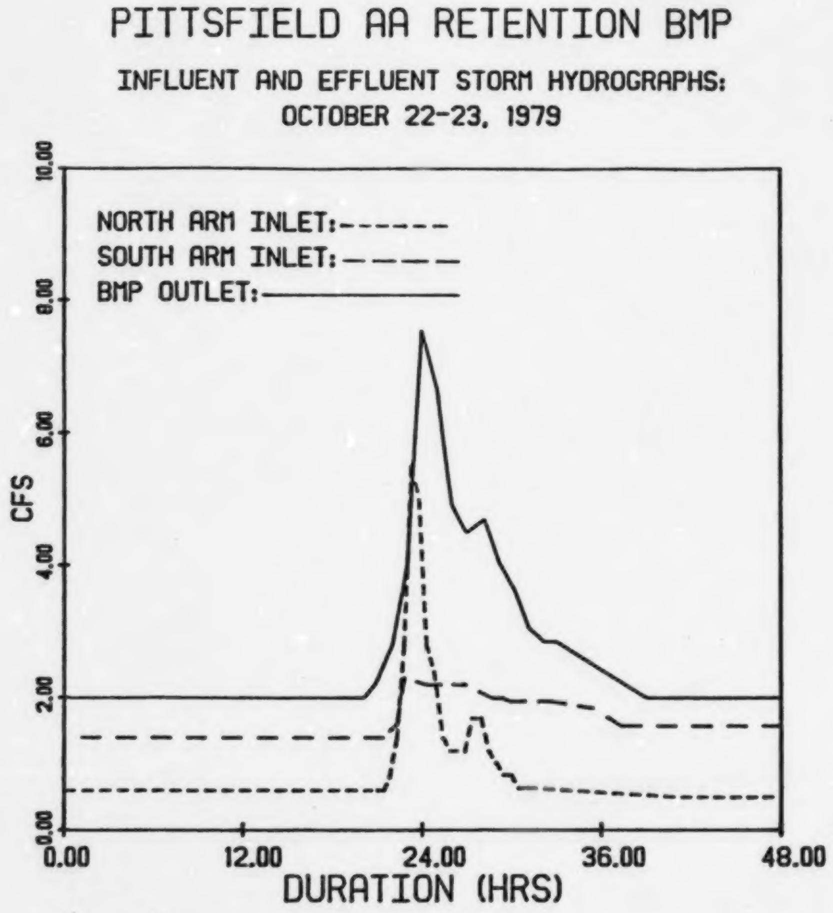
PITTSFIELD AA RETENTION BMP
INFLUENT AND EFFLUENT STORM HYDROGRAPHS:
JUNE 29 - JULY 02, 1979
NORTH ARM INLET:
SOUTH ARM INLET:
BMP OUTLET:
CFS
0.00
20.00
40.00
60.00
80.00
100.00
120.00
0.00
25.00
50.00
75.00
100.00
DURATION (HRS)

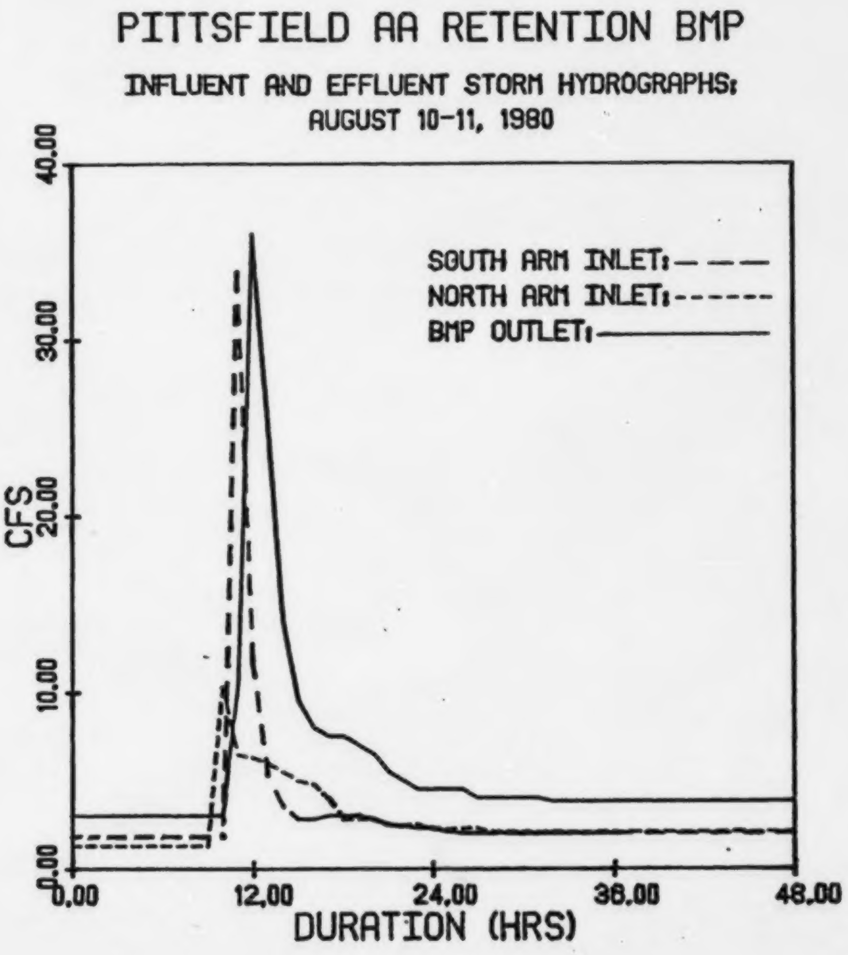
Figure IV-1



PITTSFIELD AA RETENTION BMP

INFLUENT AND EFFLUENT STORM HYDROGRAPHS:
OCTOBER 22-23, 1979

Figure IV-2



PITTSFIELD AA RETENTION BMP

INFLUENT AND EFFLUENT STORM HYDROGRAPHS: AUGUST 10-11, 1980

Figure IV-3

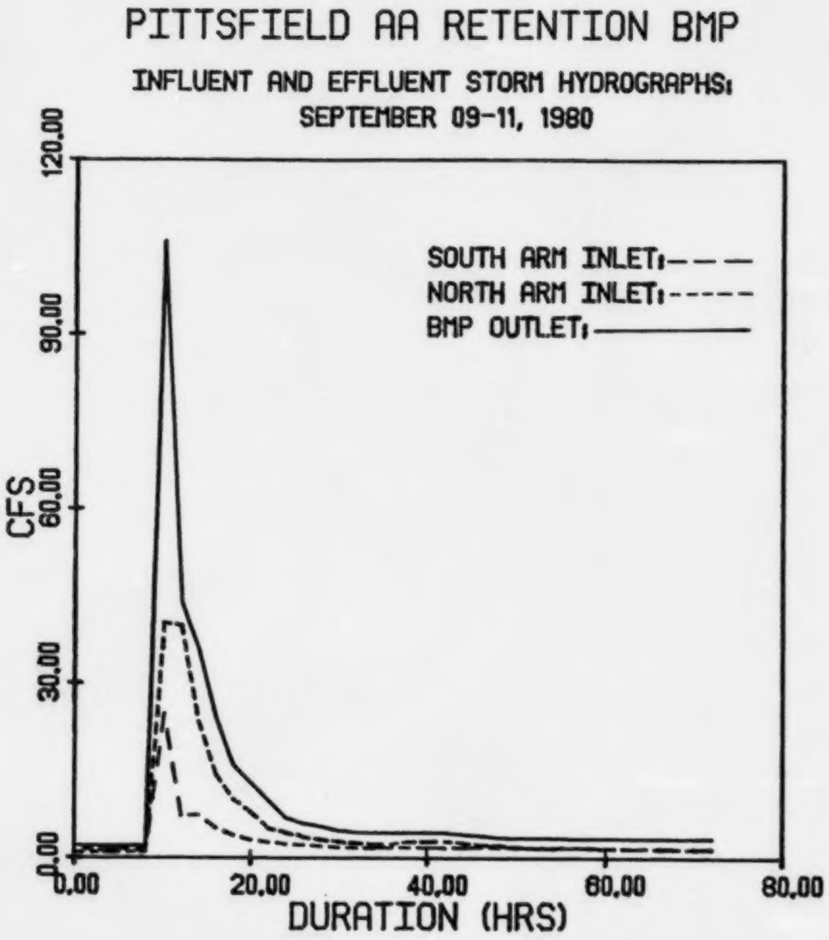

PITTSFIELD AA RETENTION BMP
INFLUENT AND EFFLUENT STORM HYDROGRAPHS:
SEPTEMBER 09-11, 1980
SOUTH ARM INLET: — — —
NORTH ARM INLET: - - - - -
BMP OUTLET: ————
CFS
0.00
30.00
60.00
90.00
120.00
0.00
20.00
40.00
60.00
80.00
DURATION (HRS)

Figure IV-4

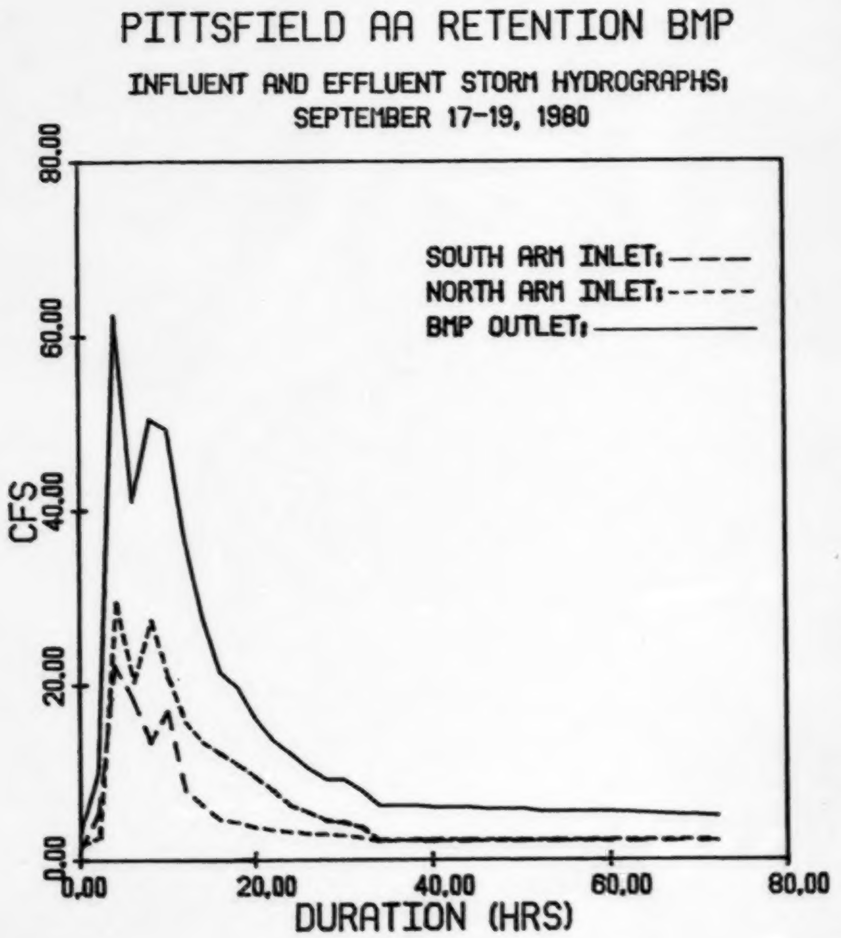
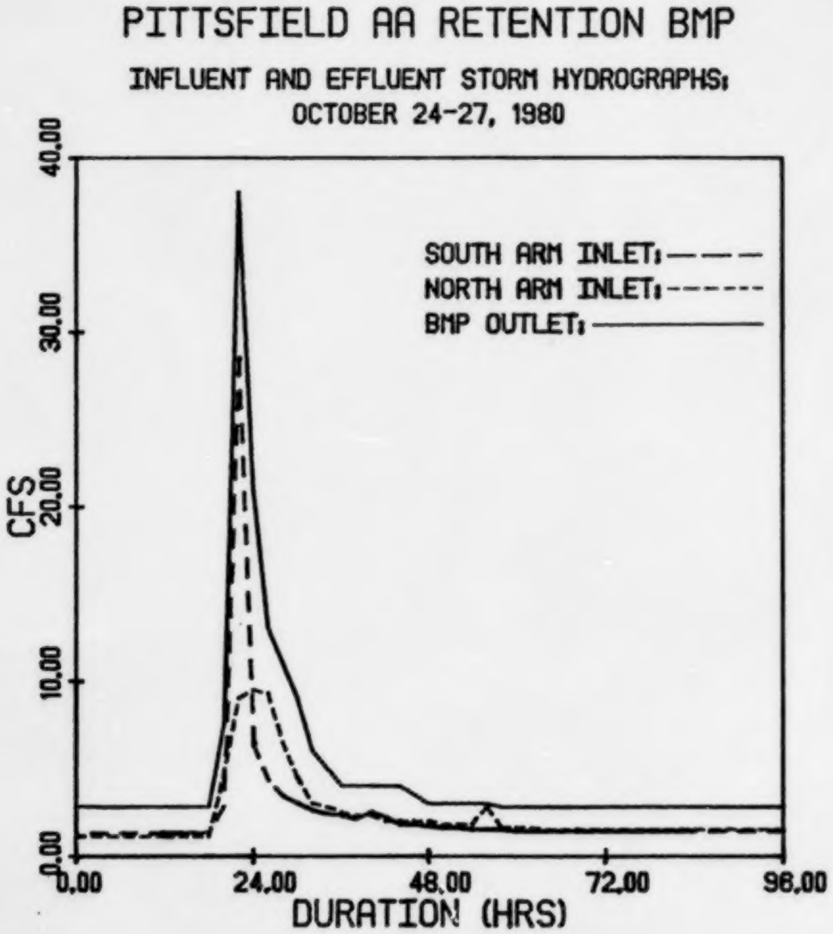

PITTSFIELD AA RETENTION BMP
INFLUENT AND EFFLUENT STORM HYDROGRAPHS;
SEPTEMBER 17-19, 1980
SOUTH ARM INLET; - - -
NORTH ARM INLET; - - - - -
BMP OUTLET; ———
CFS
0.00
20.00
40.00
60.00
80.00
0.00
20.00
40.00
60.00
80.00
DURATION (HRS)

Figure IV-5



PITTSFIELD AA RETENTION BMP

INFLUENT AND EFFLUENT STORM HYDROGRAPHS;
OCTOBER 24-27, 1980

Figure IV-6

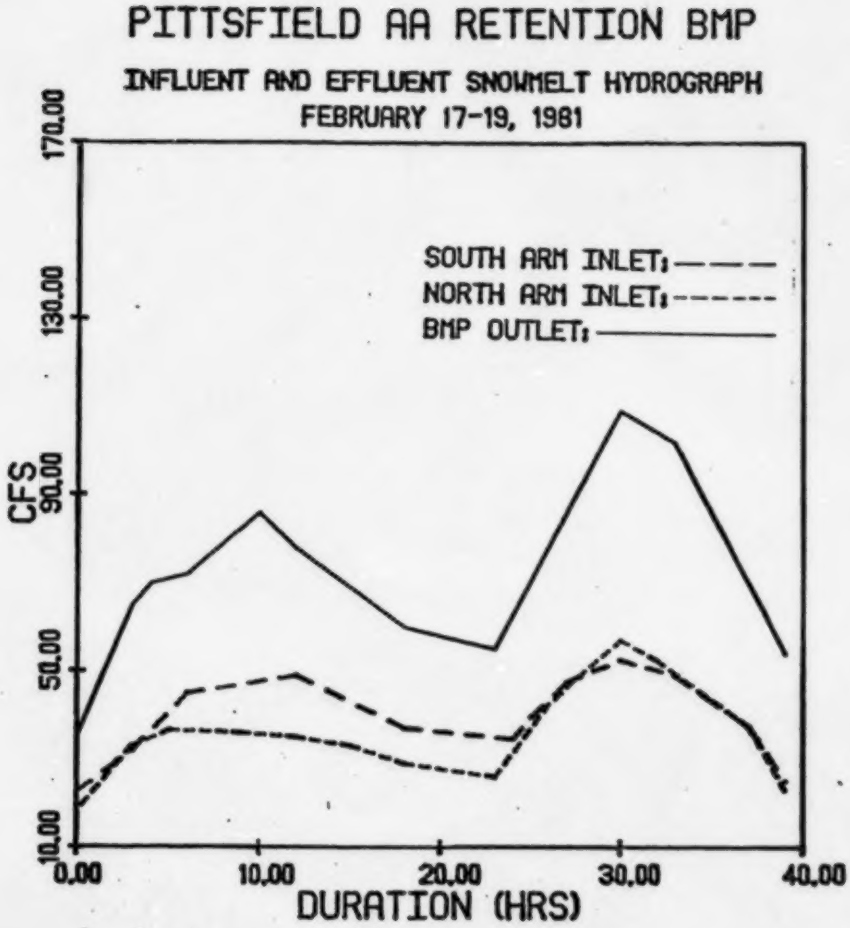

PITTSFIELD AA RETENTION BMP
INFLUENT AND EFFLUENT SNOWMELT HYDROGRAPH
FEBRUARY 17-19, 1981
SOUTH ARM INLET: — — —
NORTH ARM INLET: - - - - -
BMP OUTLET: ————
CFS
170.00
130.00
90.00
50.00
10.00
0.00
10.00
20.00
30.00
40.00
DURATION (HRS)

Figure IV-7

The higher values found in the September 1980 events can be explained by the weather conditions that preceded these events. As reported in Chapter V, August 1980 was an extremely wet month. In addition, several large rain events occurred in September 1980 before each of the monitored events. Ground conditions approached saturation and were conducive to runoff, however normal baseflow conditions did exist before each of these monitored events. Individual storm intensities also influenced these runoff values as demonstrated on the September 9th storm event. Nine tenths of an inch of rain fell during a two hour time span at this time.

The overall removal efficiency of the retention basin for total suspended solids ranged from 10-60 percent based on the total load in and out during the monitoring period. These removal efficiencies are highly dependent on a number of factors which include detention time, basin design, outlet structure design and baseflow concentrations. As shown in the October 1979 storm survey, a small rain shows low removal efficiencies due to low loading rates and comparatively high baseflow concentrations. The background suspended solids level in the retention pond are in the range of 14-17 mg/l. This level of suspended solids is somewhat higher than is generally found in storm drains during dry weather flow periods. For this particular storm event, subtracting the baseflow component from the total load results in changing the removal efficiency from 9% to 45% (See Table IV-2).

Storm intensity also influences removal efficiencies as demonstrated in the September 9, 1980 storm event where nine tenths of an inch of rain fell in less than two hours.

Besides shortening the settling time of the solids in the retention basin, intense runoff apparently causes a scouring effect at the outlet structure. As mentioned earlier, the basin was designed as a flood relief basin with no thoughts of water quality control in mind. The outlet structure is a 60' long weir structure. Sediment and debris tend to build up around the base of the outlet weir until an intense flow resuspends the material and washes it up and over the weir. Further discussion of retention times, peak loads and other factors are presented in the discussion section.

Particle size data (Table IV-9-15) shows a clear shift in particle size distribution between the inlet and outlet stations. The outlet station has a larger percentage of smaller sizes reflecting the settling of the larger particles in the basin as would be expected. In addition, a comparison of particle size distribution between the two inlet stations shows that the south arm inlet generally has a larger percentage of smaller particle sizes than does the north inlet. This would reflect the fact that the south arm has several retention basins upstream from the sampling point and settling and removal of suspended solids is already taking place in these upstream basins.

There is virtually no change detected in the total kjeldahl nitrogen between the inlet and outlet stations. This can be explained by the fact that the soluble fraction makes up over half of the total kjeldahl nitrogen measured.

Phosphorus removal efficiencies vary greatly and range between 0% removal to 55% removal. Measurements of soluble and insoluble levels of phosphorus show that most of the phosphorus is in the insoluble form. This would suggest

TABLE IV-9

PARTICLE SIZE DISTRIBUTION

LOCATION: Pittsfield - Ann Arbor Retention Basin
DATE: June 30 - July 6, 1979

	MICRON SIZE	Composite 1		Composite 1A		Composite 2		Composite 3		Composite 4	
		Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.
South Arm Inlet	>60	17	160	6.7	150	2.2	84	---	---	---	---
	10-60	32	300	13	290	18	690	6.4	120	7	83
	4-10	8.3	78	37	830	16	610	1.5	28	4.1	48
	1-4	---	---	29	650	10	380	7.9	150	1.0	12
	<1	2.4	23	8.6	190	9.5	360	6.4	120	2.0	24
North Arm Inlet	>60	6.9	160	---	---	29	2,600	4.1	72	*	
	10-60	180	4,200	---	---	70	6,300	6.0	110		
	4-10	30	700	---	---	38	3,400	---	---		
	1-4	12	280	---	---	9.8	890	2.0	35		
	<1	2.3	54	---	---	1.4	130	2.0	35		
Outlet	>60	2.9	110	---	---	7.9	1,000	12	410	8.5	220
	10-60	12	470	---	---	16	2,100	16	550	2.0	51
	4-10	8.1	320	---	---	36	4,700	13	450	2.0	51
	1-4	4.1	160	---	---	17	2,200	2.8	96	2.0	51
	<1	2.0	78	---	---	1.6	210	2.8	96	2.4	62

TABLE IV-10

PARTICLE SIZE DISTRIBUTION

LOCATION: Pittsfield-Ann Arbor Retention Basin   DATE: October 1979

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.	Composite 4 Conc. mg/l	Composite 4 Load lb.
South Arm Inlet	>60	1	5	6	60	0	---		
	4-60	19	46	15.5	160	12	90		
	<4	10	24	0.5	5	5	37		
North Arm Inlet	>60	11	56	<10$^+$	<25	<10$^+$	<26		
	4-60	123	620						
	<4	6	30						
Outlet	>60	0	---	0	---	---	---	0	---
	4-60	15	240	39	440	9	90	7	70
	<4	15	240	4	45	7	70	10	90

$^+$ TSS <10 mg/l.

TABLE IV-11

LOCATION: Pittsfield-Ann Arbor Retention Basin

DATE: August 10-11, 1980

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.
South Arm Inlet	>125	<2	<40		
	125-62.5	<2	<40		
	62.5-10	18	360		
	10-4	9	180		
	4-1	10	200		
	<1	3	60		
North Arm Inlet	>125	<2	<42		
	125-62.5	<2	<42		
	62.5-10	25	530		
	10-4	11	230		
	4-1	7	150		
	<1	5	110		
Outlet	>125	<2	<60	<2	<23
	125-62.5	<2	<60	<2	<23
	62.5-10	9	270	7	80
	10-4	5	150	9	104
	4-1	8	240	9	104
	<1	5	150	3	35

TABLE IV-12

PARTICLE SIZE DISTRIBUTION

LOCATION: Pittsfield-Ann Arbor Retention Basin

DATE: September 9-11, 1980

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.
South Arm Inlet	>125	<2	190	<2	26		
	125-62.5	<2	190	5	65		
	62.5-10	20	1,900	9	120		
	10-4	17	1,600	4	52		
	4-1	10	940	4	52		
	<1	3	280	6	77		
North Arm Inlet	>125	8	210	<10+	<95		
	125-62.5	7	180	---			
	62.5-10	34	890	---			
	10-4	16	420	---			
	4-1	17	450	---			
	<1	4	100	---			
Outlet	>125	<2	<230	<2	<53	<2	<47
	125-62.5	<2	<230	<2	<53	<2	<47
	62.5-10	29	3,400	<2	<53	8	190
	10-4	7	810	9	240	7	160
	4-1	12	1,400	10	270	7	160
	<1	4	460	6	160	2	47

+ TSS <10 mg/l.

TABLE IV-13

PARTICLE SIZE DISTRIBUTION

LOCATION: Pittsfield-Ann Arbor Retention Basin DATE: September 17-19, 1980

		Composite 1		Composite 2		Composite 3		Composite 4	
	MICRONS SIZE	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.
South Arm Inlet	>125	<2	<130	<2	<47	3	36		
	125-62.5	<2	<130	<2	<47	<2	<24		
	62.5-10	11	720	6	140	3	36		
	10-4	20	1,300	9	210	6	73		
	4-1	13	850	9	210	4	48		
	<1	7	460	<1	<24	3	36		
North Arm Inlet	>125	3	140	<2	<22	<2	<23		
	125-62.5	<2	<90	<2	<22	<2	<23		
	62.5-10	13	590	<2	<22	<2	<23		
	10-4	19	860	9	100	7	79		
	4-1	12	540	11	120	8	90		
	<1	8	360	3	24	5	56		
Outlet	>125	<2	<220	<2	<70	<2	<55	<2	<52
	125-62.5	6	650	<2	<70	<2	<55	<2	<52
	62.5-10	17	1,800	<2	<70	4	110	3	77
	10-4	<2	<220	12	420	10	280	<2	<52
	4-1	11	1,200	5	180	8	220	7	180
	<1	6	650	8	280	4	110	4	100

TABLE IV-14

PARTICLE SIZE DISTRIBUTION

LOCATION: Pittsfield-Ann Arbor Retention Basin DATE: October 24-27, 1980

		Composite 1°		Composite 2		Composite 3		Composite 4	
	MICRON SIZE	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.
South Arm Inlet	>125	<2	<5	<2	<29	<2	<11	<2	<5
	125-62.5	10	24	<2	<29	5	27	<2	<5
	62.5-10	120	290	23	340	20	110	3	8
	10-4	88	210	20	290	7	37	6	16
	4-1	35	84	14	200	<2	<11	<2	<5
	<1	17	41	<2	29	<2	<11	<2	<5
North Arm Inlet	>125	4	90	<10+	<100	<10+	<75		
	125-62.5	4	90						
	62.5-10	19	430						
	10-4	27	610						
	4-1	8	180						
	<1	5	110						
Outlet	>125	<2	<87	<2	<28	<2	<18	<2	<34
	125-62.5	<2	<87	<2	<28	<2	<18	3	52
	62.5-10	3	130	<2	<28	4	37	<2	<34
	10-4	12	520	14	200	6	55	<2	<34
	4-1	7	300	2	28	7	64	5	86
	<1	<2	<87	3	42	2	18	7	120

° - Grab Sample.
+ - TSS <10 mg/l.

TABLE IV-15

PARTICLE SIZE DISTRIBUTION

LOCATION: Pittsfield-Ann Arbor Retention Basin DATE: February 17-19, 1981 (Snow Melt)

	MICRON SIZE	Composite 1		Composite 2		Composite 3		Composite 5		Composite 6		Composite 8		Composite 9	
		Conc. mg/1	Load lb.	Conc. mg/1	Load lb.	Conc. mg/1	Load lb.	Conc. mg/1	Load lb.	Conc. mg/1	Load lb.	Conc. mg/1	Load lb.	Conc. mg/1	Load lb.
South Arm Inlet	>125	5	70	10	360	<2	<130	<2	64	<2	<72	10	500	<2	160
	125-62.5	4	60	10	360	12	770	10	320	<2	<72	<2	100	<2	160
	62.5-10	25	360	75	2,700	41	2,600	12	390	17	620	40	2,000	19	1,500
	10-4	16	230	26	920	28	1,800	11	350	7	250	28	1,400	21	1,700
	4-1	12	170	24	850	25	1,600	10	320	4	140	26	1,300	24	1,900
	<1	3	40	5	180	4	260	7	220	2	72	6	300	6	480
North Arm Inlet	>125	<2	30	<2	60	<2	80	<2	<50	<2	<60	<2	<90	<2	120
	125-62.5	6	90	10	280	<2	80	<2	<50	4	130	<2	<90	<2	120
	62.5-10	34	490	29	810	15	620	9	230	39	1,300	51	2,300	20	1,200
	10-4	26	380	46	1,300	13	540	7	180	19	610	31	1,400	15	920
	4-1	20	290	27	760	22	920	12	300	14	450	26	1,200	21	1,300
	<1	4	60	8	220	7	290	6	150	6	190	12	550	7	430
Outlet	>125	<2	<50	4	250	<2	140	<2	<100	<2	<120	<2	<190	3	410

that phosphorus removal efficiencies would coincide with total suspended solids removal efficiencies. However, no statistical relationship could be determined.

BOD and COD removal efficiencies tend to be low (10-20%) with a few unexplainable variations. In addition, it is found that grease and oil are not retained in the retention basin at all. This indicates that the grease and oil does not adsorb to suspended solids but is more likely surface oriented. A floating oil boom across the outlet structure would be a very effective means of removing this surface grease and oil.

Heavy metals results show that metals do settle out consistently. However the removal efficiencies do vary. These variations in removal efficiencies can be associated with the variations seen in the total suspended solids removals. In general the metals are mostly in the insoluble form and would be expected to be associated with and influenced by sedimentation processes. Long settling times in the basin result in better removal efficiencies as is true with total suspended solids removal. Lead has the greatest and most consistent removal efficiencies among the heavy metals monitored.

The results of the fecal coliform monitoring program (Table IV-16) indicate that the retention time in the basin is not long enough for coliform die off to occur. Coliform levels that enter the basin usually leave at similar concentrations.

Examination of the snow melt data shows that runoff during snow melt periods also contribute large quantities of

TABLE IV-16
Fecal Coliform/Fecal Streptococcus
Pittsfield - Ann Arbor Retention Basin

Station	Date/Time		Instantaneous Flow	Fecal Coliform (CFU/100)	Fecal Streptococcus (CFU/100)	Fecal Coliform Fecal Streptococcus
South Arm Inlet	10/21/79	12:00	1.4	1,400	230	6.1
	10/23/79	21:10	1.4	<10,000	<10,000	1.0
	10/23/79	22:40	2.3	300,000	60,000	5.0
	10/24/79	08:10	1.8	20,000	10,000	2.0
North Arm Inlet	10/21/79	12:00	0.5	7.400	2,000	3.7
	10/23/79	20:15	0.6	<10,000	<10,000	1
	10/23/79	23:40	4.9	2,900,000	280,000	10.4
	10/24/79	03:45	1.7	960,000	140,000	6.9
	10/24/79	07:45	0.5	91,000	50,000	1.8
Outlet	10/21/79	12:00	2	34,000	4,500	7.6
	10/23/79	18:00	2	<10,000	10,000	1
	10/23/79	23:00	4	<10,000	10,000	1
	10/24/79	01:00	6.6	<10,000	10,000	1
	10/24/79	09:00	2.8	150,000	50,000	3.0

TABLE IV-16 (Continued)

Fecal Coliform
Pittsfield - Ann Arbor Retention Basin

Station	Date/Time		Instantaneous Flow (cfs)	Fecal Coliform (CFU/100
South Arm Inlet	9/09/80	08:30	49	670,000
	9/09/80	09:30	40	75,000
	9/09/80	15:30	18	42,000
	9/10/80	09:00	2.5	31,000
North Arm Inlet	9/09/80	09:15	5	240,000
	9/09/80	10:15	25	TNTC
	9/09/80	15:45	5.5	66,000
	9/10/80	08:30	1.8	10,000
Outlet	9/09/80	09:00	25	150,000
	9/09/80	10:00	108	740,000
	9/09/80	15:00	32	31,000
	9/10/80	08:40	5.5	42,000
South Arm Inlet	9/17/80	04:00	29.5	49,000
	9/17/80	11:30	18	15,000
	9/17/80	16:30	12	35,000
	9/18/80	09:00	3.7	14,000
North Arm Inlet	9/17/80	04:30	15.5	44,000
	9/17/80	11:00	12	11,000
	9/17/80	16:00	4.8	8,200
	9/18/80	09:00	2.5	96,000
Outlet	9/17/80	04:25	55	44,000
	9/17/80	09:55	50	21,000
	9/17/80	16:25	22	27,000
	9/18/80	08:30	8.5	60,000

TABLE IV-16 (Continued)

Fecal Coliform/Fecal Streptococcus
Pittsfield - Ann Arbor Retention Basin

Station	Date/Time	Instantaneous Flow (cfs)	Fecal Coliform (CFU/100)	Fecal Streptococcus (CFU/100)	Fecal Coliform / Fecal Streptococc
South Arm Inlet	02/17/81 11:50	22.1	6,000		
	02/17/81 14:10	32.6	3,000		
	02/17/81 23:30	49.5	1,500		
	02/18/81 06:18	37.4	2,300		
	02/18/81 10:25	35.0	1,500		
	02/18/81 14:00	44.6	2,300		
	02/18/81 20:18	55.7	2,200	6,200	0.4
	02/19/81 06:10	37.0	1,100		
North Arm Inlet	02/17/81 12:00	19.6	2,000		
	02/17/81 14:20	32.0	3,000		
	02/17/81 22:45	37.0	1,090		
	02/18/81 06:35	29.5	1,500		
	02/18/81 10:40	26.0	1,600		
	02/18/81 14:00	44.0	1,300		
	02/18/81 22:30	46.4	2,300	1,800	1.3
	02/19/81 06:25	22.6	1,500		
Outlet	02/17/81 12:10	36.2	5,500		
	02/17/81 14:30	63.7	2,000		
	02/17/81 22:30	85.8	1,090		
	02/18/81 06:45	58.0	1,700		
	02/18/81 14:00	78.4	1,500		
	02/18/81 22:50	95.8	2,300	6,100	0.4
	02/19/81 06:35	54.0	2,100		

pollutants to both inlet branches of the Pittsfield-Ann Arbor Retention Basin. Table IV-7 summarizes the pollutant loadings found during the February 1981 snow melt event. This was the major snow melt of the winter after which most areas were clear of snow. The data indicates that the retention basin does have some removal capability for all parameters monitored with total suspended solids and total iron having the highest removal efficiencies. Particle size data indicates that generally snow melt runoff contains larger particle sizes overall in comparison with rain event survey periods. This would tend to indicate that snow runoff may be more effectively controlled by sedimentation than rainfall runoff waters. As seen in rainfall events, total kjeldahl nitrogen is present more in the soluble form, whereas the metals are prevalent in the insoluble form. Soluble phosphorus is also slightly more prevalent than insoluble phosphorus during the snow melt period. Fecal coliform levels are found to be very low for both inlets.

Comparing event mean concentrations (EMC's) of the snow melt event to the rain event's indicate that on the South Arm inlet the EMC's for most parameters (TDS, TSS, TKN, SKN, TP, SP, COD, T-Fe, S-Fe) monitored were considerably higher during the snow melt than found during the rain events (Tables IV-17-19). However, this was not found to be the case on the North Arm inlet. Event mean concentrations on the North inlet for the snow melt tend to be in the same range as those monitored during the rain events.

TABLE IV-17

Event Mean Concentrations

STATION: Pittsfield Ann Arbor Retention Basin South Arm Inlet   DATE: Period of Record

Average Concentration	June 1979	October 1979	August 1980	Sept. 9 1980	Sept. 17 1980	October 1980	February 1981 Snow Melt
TDS mg/l:	386	566	459	478	348	489	605
TSS mg/l:	52	23	40	47	41	68	102
Total Alkalinity mg/l:	---	---	350	123	148	232	93
BOD mg/l:	<2.4	3.6	5	8.5	4.7	7.5	6.1
NO_3N mg/l:	0.43	0.18	0.13	0.24	0.36	0.32	0.50
TKN mg/l:	1.0	0.48	0.75	1.0	0.79	1.0	1.9
SKN mg/l:	0.82	0.35	0.37	0.49	0.53	0.63	1.4
TP mg/l:	0.13	0.04	0.07	0.13	0.12	0.11	0.33
SP mg/l:	0.02	0.01	<0.01	<0.01	0.02	0.01	0.18

TDS - Total Dissolved Solids
TSS - Total Suspended Solids
BOD - Biological Oxygen Demand
NO_3N - Nitrate
TKN - Total Kjeldahl Nitrogen
SKN - Soluble Kjeldahl Nitrogen
TP - Total Phosphorus
SP - Soluble Phosphorus

TABLE IV-17 (Continued)

Event Mean Concentrations

STATION: Pittsfield-Ann Arbor Retention Basin
South Arm Inlet
DATE: Period of Record

Average Concentration	June 1979	October 1979	August 1980	Sept. 9 1980	Sept. 17 1980	October 1980	February 1981 Snow Melt
COD mg/l:	---	---	28	32	27	26	51
T-FE mg/l:	1.4	0.78	1.0	1.6	1.2	1.6	2.1
S-FE mg/l:	0.06	0.07	0.009	0.01	0.03	0.03	0.11
T-Pb mg/l:	0.01	0.003	0.01	<0.09	0.006	0.01	0.02
S-Pb mg/l:	0.001	0.001	<0.001	<0.0009	<0.001	<0.001	0.001
T-Zn mg/l:	0.13	0.03	---	0.07	0.04	---	0.09
T-Cr mg/l:	0.05	0.01	---	0.06	0.02	---	---
T-Cd mg/l:	0.0003	<0.0001	---	0.0002	<0.0004	---	---
G&O mg/l:	---	---	---	1.9	1.5	---	3

COD - Chemical Oxygen Demand
T-FE - Total Iron
S-FE - Soluble Iron
T-Pb - Total Lead
S-Pb - Soluble Lead
T-Zn - Total Zinc
T-Cr - Total Chromium
T-Cd - Total Cadmium
G&O - Grease and Oil

TABLE IV-18

Event Mean Concentrations

STATION: Pittsfield-Ann Arbor Retention Basin North Arm Inlet DATE: Period of Record

Average Concentration	June 1979	October 1979	August 1980	Sept.9 1980	Sept. 17 1980	October 1980	February 1981 Snow Melt
TDS mg/l:	245	485	200	572	276	382	316
TSS mg/l:	<136	70	48	65	44	41	90
Total Alkalinity mg/l:	---	---	190	162	154	227	75
BOD mg/l:	<2.7	12	4	3.2	3.5	12	5.2
NO_3N mg/l:	0.60	---	0.53	0.35	0.49	0.36	0.70
TKN mg/l:	1.2	1.3	1.1	1.0	1.0	0.70	1.4
SKN mg/l:	0.57	---	0.44	0.55	0.48	0.63	0.94
TP mg/l:	0.26	0.49	0.16	0.19	0.16	0.33	0.23
SP mg/l:	0.03	<0.06	0.04	0.02	0.03	0.17	0.11

TDS - Total Dissolved Solids
TSS - Total Suspended Solids
BOD - Biological Oxygen Demand
NO_3N - Nitrate
TKN - Total Kjeldahl Nitrogen
SKN - Soluble Kjeldahl Nitrogen
TP - Total Phosphorus
SP - Soluble Phosphorus

TABLE IV-18 (Continued)

Event Mean Concentrations

STATION: Pittsfield-Ann Arbor Retention Basin
North Arm Inlet
Date: Period of Record

Average Concentration	June 1979	October 1979	August 1980	Sept. 9 1980	Sept. 17 1980	October 1980	February 1981 Snow Melt
COD mg/l:	---	---	42	---	33	51	43
T-FE mg/l:	2.9	2.6	1.1	1.6	1.4	1.9	2.0
S-FE mg/l:	<0.11	<0.22	0.05	0.02	0.06	0.10	0.08
T-Pb mg/l:	<0.11	<0.07	0.04	---	0.02	<0.05	0.02
S-Pb mg/l:	0.001	<0.008	0.002	<0.001	<0.0009	<0.009	0.04
T-Zn mg/l:	0.18	0.09	---	0.06	0.05	---	0.09
T-Cr mg/l:	0.02	0.02	---	0.02	0.005	---	---
T-Cd mg/l:	0.001	<0.0003	---	0.0003	<0.0003	---	---
G&O mg/l:	---	---	---	2.7	<0.99	---	3.4

COD - Chemical Oxygen Demand
T-FE - Total Iron
S-FE - Soluble Iron
T-Pb - Total Lead
S-Pb - Soluble Lead
T-Zn - Total Zinc
T-Cr - Total Chromium
T-Cd - Total Cadmium
G&O - Grease and Oil

TABLE IV-19

Event Mean Concentrations

STATION: Pittsfield-Ann Arbor Retention Basin Outlet DATE: Period of Record

Average Concentration	June 1979	October 1979	August 1980	Sept. 9 1980	Sept. 17 1980	Oct. 1980	February 1981 Snow Melt
TDS mg/l:	302	404	415	390	307	446	449
TSS mg/l:	51	27	26.5	47	34	22	75
Total Alkalinity mg/l:	---	---	326	144	130	214	82
BOD mg/l:	2.0	4.8	3.7	3.8	3.6	11	5.4
NO_3N mg/l:	0.51	0.19	0.34	0.32	0.42	0.26	0.69
TKN mg/l:	1.0	0.79	0.91	0.94	0.66	0.74	1.6
SKN mg/l:	0.62	0.62	0.49	0.52	0.44	0.50	1.1
TP mg/l:	0.14	0.07	0.12	0.13	0.13	0.20	0.38
SP mg/l:	0.03	<0.01	0.01	<0.03	---	0.09	0.14

TDS - Total Dissolved Solids
TSS - Total Suspended Solids
BOD - Biological Oxygen Demand
NO_3N - Nitrate
TKN - Total Kjeldahl Nitrogen
SKN - Soluble Kjeldahl Nitrogen
TP - Total Phosphorus
SP - Soluble Phosphorus

TABLE IV-19 (Continued)

Event Mean Concentrations

STATION: Pittsfield-Ann Arbor Retention Basin Outlet DATE: Period of Record

Average Concentration	June 1979	October 1979	August 1980	Sept. 9 1980	Sept. 17 1980	October 1980	February 1981 Snow Melt
COD mg/l:	---	---	25	23	29	31	41
T-FE mg/l:	1.9	0.81	0.99	1.5	1.0	0.86	1.8
S-FE mg/l:	0.08	0.07	0.02	0.01	0.03	0.07	0.08
T-Pb mg/l:	0.03	0.009	0.02	0.009	0.01	0.02	0.04
S-Pb mg/l:	0.001	0.001	<0.001	<0.001	<0.001	<0.004	0.002
T-Zn mg/l:	0.13	0.03	---	0.05	0.04	---	0.09
T-Cr mg/l:	0.02	0.01	---	0.005	0.003	---	---
T-Cd mg/l:	0.0005	0.0006	---	<0.0003	<0.0002	---	---
G&O mg/l:	---	---	---	<3.4	1.4	---	3.3

COD - Chemical Oxygen Demand
T-FE - Total Iron
S-FE - Soluble Iron
T-Pb - Total Lead
S-Pb - Soluble Lead
T-Zn - Total Zinc
T-Cr - Total Chromium
T-Cd - Total Cadmium
G&O - Grease and Oil

Discussion

As stated in the objectives for this study, it was anticipated that removal of pollutants in the Pittsfield-Ann Arbor retention basin would primarily be accomplished by sedimentation of suspended materials. The principle factor under ideal conditions which affects sedimentation efficiency is the detention time provided in the basin. In an ideal basin the detention time will determine the critical settling velocity. All particles having settling velocities higher than the critical value will be removed from the basin. Many real world factors affect the actual performance of a basin and the magnitude of the deviation from ideal conditions will determine the actual efficiency achieved.

Table IV-20 shows the average and minimum theoretical detention time (based on volume displacement) in the retention basin for each of the monitored runoff events. Peak suspended solids concentration, the event mean concentration, and overall percent removal levels are also shown. Suspended solids are provided as this parameter is the primary constituent influenced by sedimentation. Other materials in the particulate form will follow the suspended solids levels to some degree depending on the size and specific gravity of the particles with which they are associated.

The performance of the retention basin (based on % removal of the total load) is lower than was initially projected using ideal basin assumptions at the beginning of the study. Several factors appear to be influencing the actual performance of this basin including site specific

TABLE IV-20

Detention Time for Monitored Events
Pittsfield - Ann Arbor Retention Basin

Date (mg/l)	Min. Detention* Time (hrs.)	Ave. Detention* Time (hrs.)	%TSS	Peak TSS Conc. Removal	Event Mean TSS Conc. (mg/l)
Snow Melt 1981	2.5	3.7	27	110	75
6-30-79	2.5	23	44	79	51
9-11-80	2.6	19	10(26)**	52	47
9-17-80	4.6	15	17(44)**	40	34
10-24-80	7.3	32	57(87)**	24	20
8-10-80	7.7	36	39(70)**	28	27
10-22-79	37	105	9(45)**	43	27

* Theoretical time based flow rate and volume displacement.
** Background corrected.

conditions and the basin design. Site specific conditions need to be understood and accounted for when using the results of this work in other applications. Basin design factors can be altered in future basin designs to improve the basin performance.

Two main factors, background suspended solids and other pollutant concentrations, and the particle characteristics for this drainage system, directly affect the percent removal levels measured for the basin. Using the ideal basin approach it would be expected that during smaller storms with lower peaks and average flows (i.e. longer detention times) that the performance of the basin on a percent removal basis would be the highest. However, as shown in Table IV-2, the October 1979 storm which was a small event, had the lowest overall percent removal. The calculation of this removal percentage, however, includes all of the load during the monitoring period including both the background suspended solids level and the increase load during the storm. In the case of small storms, the background level in the retention basin (are 12 mg/l TSS) is a significant load compared to the event mean concentration of 16 mg/l for the October storm. Recalculating the removal efficiency for this storm using only the suspended solids increased level above background, results in a removal efficiency of 45%. Other pollutant removals are also impacted by background levels. An example of the impact background concentrations have for these other parameters is shown in Table IV-2.

The impact of the background levels highlight that when examining and reviewing the rain event runoff data, care must be taken not to place too much emphasis on the actual percent removal of various materials but rather consider the removal amounts and types of mechanisms affecting the materials controlled.

A site specific condition of the South Arm inlet which effects the total load during events and the background level is that it has other retention basins upstream which will tend to reduce the amount of pollutant which is available for removal. The north arm has no control on it and thus represents the total load coming in that drainage area. The data collected during the five rain events show that a retention basin can remove some portion of the pollutant load in urban runoff. Examination and comparison of the north and south arm inlet data further supports this conclusion.

The south arm drainage area (2001 acres - 21% impervious) includes a large shopping center and airport (see land use section Chapter II) but also contains several retention basins controlling the runoff from these developments. Based on land use characteristics and our findings during the drain outlet survey and previous work, the runoff water from the south arm would be expected to be at least as contaminated on a concentration or per acre developed basis as the north arm area (2871 acres - 26% impervious). Examination of the data, however, shows that there is a dramatic difference between the event mean concentrations in the south arm and the north arm districts (Tables IV-17-18-19). Event mean concentrations for suspended soilds, total phosphorus and total lead particularly show the lower levels in the south arm. It is quite apparent that the retention basins upstream are removing materials from the south branch. Thus, much of the pollutant load, in the south arm, especially during small storms, has alraedy passed through basins similar to the one under study. Therefore, it can be expected that the percent removal of total load in this basin will be lower than if all the water entering the basin was direct from the land.

Another factor which affects the actual performance of this basin is the particle size distribution (actually measured by settling time) present in the inlet waters. It was originally anticipated that a large fraction of the suspended solids in the runoff waters would be in the upper ranges above 62 micron. The actual data collected shows that the sizes tends to be smaller and thus require longer detention times to settle from the water column. In general, all of the data collected during this study tends to show a larger portion of the particles are in the smaller ranges. The south inlet location is further impacted due to the presence of the upstream retention basins. Thus, the distribution of the particles directly impact the removal efficiencies. As the distribution moves toward the smaller sizes longer detention times will be required to maintain a target efficiency level.

The design of a retention basin and the flow conditions of urban runoff have an important impact on the performance of the basin. As mentioned previously, the Pittsfield-Ann Arbor retention basin was not designed to optimize sedimentation, as the original function of the basin was for flood control. The outlet structure for the basin is a concrete broadcrested weir which is relatively short in length, and the bottom of the basin slopes upward toward the weir resulting in only a two foot water depth at the outlet. These conditions result in high velocity contours near the outlet, particularly during the high flow periods, and the potential for scouring of material near the outlet structure.

Stormwater flows are highly variable in nature and thus tend to cause very unsteady flow patterns in the retention basin. This deviation from the "ideal basin" will generally result in reduced performance due to short circuitry, disruption of smooth settling profiles and possible disturbances in the sludge zone. In addition, the data collected duing this study indicates that the highest levels of suspended solids tend to occur during peak flow rates. Thus, the highest loads are entering the basin during the the shortest detention times and least ideal conditions. These general stormwater characteristics and specific basin design conditions were considered in evaluating the performance data.

Comparing the detention time conditions and suspended solids levels (Table IV-20) shows several trends in the data. The peak suspended solids levels, event mean concentration, and removal percentages were ranked according to the peak flow/minimum detention time and average detention of each storm. Both peak concentration and event mean concentration followed a decreasing pattern as minimum detention time increases. In addition, the percent removal of suspended solids tends to increase with increasing minimum detention time (i.e. smaller peak flows). These trends do not appear to hold for comparisons with average detention time which is based on average runoff flows. This data suggests that the peak flow rates are a significant controlling factor in the performance of the basin.

The dependance of the event mean concentrations and the basin's performance on the peak flow conditions rather than average conditions appears to be the result of the importance of the peak load quantities to the total load, the increased potential for short circuiting during high flow periods, and scouring at the outlet due to the high discharge rate. The event mean concentration for the runoff events when ranked with peak suspended solids concentration show that the event mean concentration is strongly influenced by the peak flow level. This factor tends to hold for varying storm types with differing rates of peak to average flow. The combination of high flow and high concentration results in a significant percentage of the total load for the event leaving the basin during that period and consequently raising the overall mean concentration for the event. For storms such as those in June, 1979 and September 11, 1980 which had high peak to average flow ratios (9:1 and 7:1 respectively) the event mean concentration was raised due to the sharp peak rate. Thus, when a comparison of event mean concentration to average detention time was made, the event mean concentrations did not follow the same trend as the other events of more similar peak to average ratios (2-4:1).

The influence of peak flows on the discharge of suspended solids from the basin would be expected during those periods when detention time is quite small such as snow melt and September 11, 1980 events (theo. min. detention time 2.5 hrs.). During these peak flow times, the suspended material has a much shorter period in which to settle and the most severe short circuiting and turbulance in the basin is probably occurring. High suspended solids levels are entering the basin at this time and some of the solids may be passing through the basin in a much shorter time than the theoretical time of 2-3 hours. This situation can be expected based on the mechanisms involved in the sedimentation process in a dynamically loaded system. However, the increase in concentration also occurs for storms where the peak flows are not as high and the minimum detention time is in the range of 7-8 hours (August 10, October 24, 1980, Table IV-20). For these events the highest concentrations occurred during the peak even though it is highly unlikely that the load entering the basin has reached the outlet structure. This suggests that scouring is probably occurring at the outlet, resulting in high concentrations during the peak discharge period. Thus, even though the runoff load entering the basin may be settling to the bottom, previously deposited material near the outlet is being flushed from the basin. As a result, the performance of the basin is less than would be expected and the peak flow becomes a controlling factor in the performance of the basin for these storms also.

Based on this evaluation, several possibilities exist for improving the efficiency of retention basins in trapping suspended material. The problem of scouring can be minimized by adjustments in the outlet conditions. Deeper water depths coupled with better control of peak flows or providing a more distributed discharge would help minimize the scour problem. Further the data would indicate that control of the peak flows may be one of the most important factors in the efficiency of a retention basin. Outlet structures which lower the maximum outlet rate could provide better removal during the peak periods. Slowing the discharge rate will lengthen the detention time in the basin for the peak load periods and thus improve removal efficiency. Another possibility is increasing the size of the basin which will tend to dampen the peak to average flow rates, and will provide additional detention time in which settling can occur. The next section, describing the wetlands, is an example of a larger basin without a restricted outlet. The overall impact of the larger detention times raises the removal levels into the 70-90% range as will be shown.

In summary, the retention basin does remove suspended material from the runoff waters. Site specific conditions, particularly the impact of upstream retention basins, affect the actual percentage removal values for the basin. Higher percent removal values may be achieved in other areas without this influence. Peak flow conditions appear to significantly influence the basin performance and scouring is probably occurring on a regular basis near the outlet. Improvement in the performance of this type of basin could be achieved in future designs by attempting to minimize the scouring problem and improving peak flow control.

Finally, it should be noted that even though the overall percentage removal levels for this bsin may seem low (10-60%) a large quantity of pollutants are being retained. For the seven events monitored during this study, over 36,000 pounds of suspended material were retained in the basin.

Cost - Pittsfield-Ann Arbor Retention Basin

The construction of the Pittsfield-Ann Arbor retention basin and associated drain improvement project was undertaken primarily in the construction seasons of 1977 and 1978. The costs of constructing the retention basin are shown in Table IV-21. These costs are based on the actual contractor costs as charged during the project. Land acquisition costs were reasonably high (approximately $12,500/acre) because of the location within a developed portion of the City. Engineering and legal fees are standard fees based on percentage of construction. The actual engineering and legal costs for the basin itself were not broken out from the total project so a ratio of total project construction cost to basics construction cost was used to estimate these fees.

SWIFT RUN WETLANDS

Introduction

Natural wetlands have the ability to accomplish many of the stormwater management objectives of artificially constructed retention basins. Wetlands can reduce stormwater velocity and buffer peak volumes so that pollutants can settle out and also offer tremendous flood control abilities. Besides offering ways to improve the quality of stormwater runoff, wetlands also provide fish and wildlife habitats, recreational opportunities and aesthetic beauty.(1) The Swift Run Wetlands has been acquired by the Office of the Drain Commissioner in order to incorporate storage and water quality improvements in the Swift run Drainage District. The objective of the evaluation of this unique naturally occurring wetlands is to determine the level of water quality improvement which can be expected from this type of physical environment.

TABLE IV-21

CAPITAL COST
Pittsfield - Ann Arbor Retention Basin

Division III - Retention Basin No. 1

Quantity	Unit	Description	Amount
2.1	Ac.	Clearing and Grubbing	$3,150.00
148,678	CY	Cut and Fill Excavation	74,339.00
1,440	CY	Excavation for Embankment Foundation	1,152.00
3,704	CY	Embankment Construction	2,963.00
1	LS	Demolition of Existing Structures	1,500.00
1	LS	Outlet Control Structure	62,349.00
75	LF	24-inch RCSP, ASTM C76-11	1,367.25
360	LF	Chain Link Fence	3,801.60
1066	SY	Rip Rap	2,132.00
52,233	SY	Final Grading, Topsoil and Seeding	13,058.25
2460	SY	Sodding	2,214.00
1	LS	Plantings	18,000.00
TOTAL			186,026.30
Land Acquisition			128,750.00
Engineering Fees, Legal			20,000.00

Data Collection

As described earlier in this report, monitoring of the Swift Run Wetlands consisted of the determination of flow and pollutant levels at the inlet and outlet stations located on the wetlands. The inlet stations consisted of a Stevens level recorder housed in a steel box and anchored over a stilling well. The stilling well was anchored against the upstream side of the culvert as it passed under the expressway in the middle of the channel. A Manning automatic discrete sampler with a float switch activation setup was used to collect water samples on a time basis. The sampler was secured under a 55-gallon steel drum anchored to a cement pad. Depending on the predicted storm size and duration, the samplers were set to collect 500 ml samples every fifteen or thirty minutes. Samples were collected throughout the runoff period. The outlet station consisted of a free standing stilling well anchored to the outlet weir structure. A Manning dipper flow recorder was housed in a steel security box over the stilling well. A Manning automatic composite sampler with a 15-liter sample jug was housed in another steel security box which was anchored to a cement pad. The sample line and flow recorder - sampler innerconnect cord were housed in conduit for protection against vandalism. By using theoretical flow values and actual measured flow values, a flow/depth relationship was developed at the outlet that enabled the flow recorder to be set to measure actual flow. By using a programmed module the flow recorder was set to pulse the sampler to take flow proportional samples automatically. Numerous attempt were made to develop a flow curve for the inlet structure without success. Most of the problems encountered were associated with large amounts of sediment blocking parts of the pipe as it went under the expressway which caused unusual flow patterns in the culvert. However level records from the Stevens recorder were compared to the flow charts at the outlet for many rain events and it was felt that the outlet flow curve could be safely used to composite the discrete inlet samples collected over time.

Generally for the rainfall events, one to two composites were made to represent the major runoff portion of the event and one or two additional samples were composited to represent the tail portion of the curve and background conditions. Thus, a series of sequential composite samples were obtained to represent each runoff event. During the snow melt event, grab samples were taken at predetermined times throughout the elevated runoff period. Flows were determined using the outlet stage-discharge curve and depth measurements taken at the time of the grab sample collection.

Also mentioned earlier, samples which were composited were either analyzed immediately by the laboratory or preserved by approved USEPA procedures. All compositing and preservation was performed in the laboratory as all stations were in close proximity to the office. Analytical procedures followed approved methods. Quality control and quality assurance procedures are presented in Appendix I.

Results

Five rain events and one snow melt event were monitored over a two year period. Summaries of the pollutant loadings entering and leaving the basin are presented in Table IV-22-27. These summary tables are based on total loadings entering and leaving the wetlands during the runoff period. The loadings presented include both baseflow conditions and loadings from the storm runoff period. Individual parameter values for each composite are presented in a separate data report. Generally, the first composite sample represents the beginning period of runoff, the second sample the middle portion of the storm and the third sample the tail portion of the curve and subsequent samples represent the baseflow conditions. Sampling at the outlet station was continued for several days following a storm to insure water entering during the storm had passed through the basin. These composite cutoff times are only estimates and the actual composite cutoffs depend on the storm and runoff characteristics for each event.

Figures IV-8-12 show the runoff hydrographs for the outlet station for each event. As mentioned earlier, the outlet station was used to composite the inlet discrete samples because of the difficulty in establishing a sound inlet flow curve. Flow ranges and patterns are similar for all storm events although some influence from the newly constructed upstream retention basin at the landfill finished between the 1980 and 1981 monitored events would be expected to be seen in the 1981 monitored events. Runoff coefficients for the stations are fairly constant for allof the events (Table IV-28).

TABLE IV-22

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

August 20-22, 1980

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Inlet	1,236,000	23,000	5,300	10,500	227	124	75	62	13.3	4.4
Outlet	1,266,000	18,600	390	7,800	282	5.8	73	56	7.1	3.9
Pollutant Removed		4,400	4,910	2,700	-55	118.2	2	6	6.2	.5
Percent of Inlet Retained		19	93	26	(-24)	95	x	10	47	11

x = 0±10%

TABLE IV-22 (Continued)

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

August 20-22, 1980

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Inlet	1,236,000	2,562	112.0	3.63	1.30	0.07	3.30	0.67	0.035	288
Outlet	1,266,000	2,490	20.3	<1.59	<0.18	<0.07	2.83	0.35	<0.015	100
Pollutant Removed		72	91.7	<2.04	1.11	>0	.47	0.32	<0.024	188
Percent of Inlet Retained		x	82	>56	85	x	14	48	>62	65

x = 0±10%

TABLE IV-23

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

February 17-20, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Swift Run Wetlands Inlet	3,881,000	45,800	20,260	15,510	1,997	170	418	268	102	69
Swift Run Wetlands Outlet	3,881,000	55,700	11,140	16,820	1,717	154	422	330	64	37
Pollutant Removed		-9,900	9,120	(-1,310)	280	16	(-4)	-62	38	32
Percent of Inlet Retained		(-18)	45	x	14	x	x	(-23)	37	46

x = 0±10%

TABLE IV-23 (Continued)

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

February 17-20, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Swift Run Wetlands Inlet	3,881,000	10,160	549	14	3.2	<0.23	14.2	---	---	744
Swift Run Wetlands Outlet	3,881,000	10,680	409	24	2.1	<0.24	13.7	---	---	626
Pollutant Removed		(-520)	140	(-10)	1.1	(-0.01)	0.5	---	---	118
Percent of Inlet Retained		x	25	(-71)	34	x	x	---	---	16

x = 0±10%
-- = parameter not monitored during this survey

TABLE IV-24

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

April 11-13, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Swift Run Wetlands Inlet	563,000	15,100	2,880	4,650	70	27.5	36	23.8	4.9	1.0
Swift Run Wetlands Outlet	563,000	13,600	525	3,720	78	6.3	25.9	24.3	2.20	.70
Pollutant Removed		1,500	2,355	930	-8	21.2	10.1	-0.5	2.7	0.3
Percent of Inlet Retained		10	82	20	(-11)	77	28	x	55	30

x = 0±10%

TABLE IV-24 (Continued)

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

April 11-13, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Swift Run Wetlands Inlet	563,000	970	38.4	1.1	0.34	<0.04	---	---	---	---
Swift Run Wetlands Outlet	563,000	1,120	15.2	<0.85	0.08	<0.04	---	---	---	---
Pollutant Removed		(-150)	23.2	<0.25	0.26	---	---	---	---	---
Percent of Inlet Retained		(-15)	60	>23	76	---	---	---	---	---

-- = parameter not monitored during this survey

TABLE IV-25

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

April 13-17, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Swift Run Wetlands Inlet	894,000	18,000	7,770	7,600	111	69	74	47.6	10.2	2.5
Swift Run Wetlands Outlet	894,000	20,400	1,680	7,700	133	33	56	42.7	5.1	1.0
Pollutant Removed		(-2,400)	6,090	(-100)	(-22)	36	18	4.9	5.1	1.5
Percent of Inlet Retained		(-13)	78	x	(-20)	52	24	10	50	60

x = 0±10%

TABLE IV-25 (Continued)

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

April 13-17, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Swift Run Wetlands Inlet	894,000	1,450	106	2.0	0.68	<0.05	---	---	---	---
Swift Run Wetlands Outlet	894,000	1,630	52	2.0	.09	<0.05	---	---	---	---
Pollutant Removed		(-180)	54	0	.59	---	---	---	---	---
Percent of Inlet Retained		(-12)	51	x	87	---	---	---	---	---

x = 0±10%
-- = parameter not monitored during this survey

TABLE IV-26

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

April 22-26, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Swift Run Wetlands Inlet	1,199,000	23,000	4,100	11,000	153	69	79	66	7.5	2.4
Swift Run Wetlands Outlet	1,199,000	22,000	771	8,800	140	7.3	59	56	2.9	1.3
Pollutant Removed		1,000	3,329	2,200	13	61.7	20	10	4.6	1.1
Percent of Inlet Retained		x	81	20	x	89	25	15	61	46

x = 0±10%

TABLE IV-26 (Continued)

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

April 22-26, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Swift Run Wetlands Inlet	1,199,000	2,500	97	3.8	<0.45	---	---	---	---	---
Swift Run Wetlands Outlet	1,199,000	2,120	53	<1.9	<0.08	---	---	---	---	---
Pollutant Removed		380	44	>1.9		---	---	---	---	---
Percent of Inlet Retained		15	45	>50		---	---	---	---	---

-- = parameter not monitored during this survey

TABLE IV-27

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

May 29, 1981 - June 1, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Inlet	554,000	12,800	600	4,700	170	9.3	45	25	1.6	0.69
Outlet	554,000	11,100	146	3,400	77	0.84	33	33	2.3	1.40
Pollutant Removed		1,700	454	1,300	93	8.5	12	(-8)	(-0.7)	(-0.71)
Percent of Inlet Retained		13	76	28	55	91	27	(-32)	(-43)	(-100)

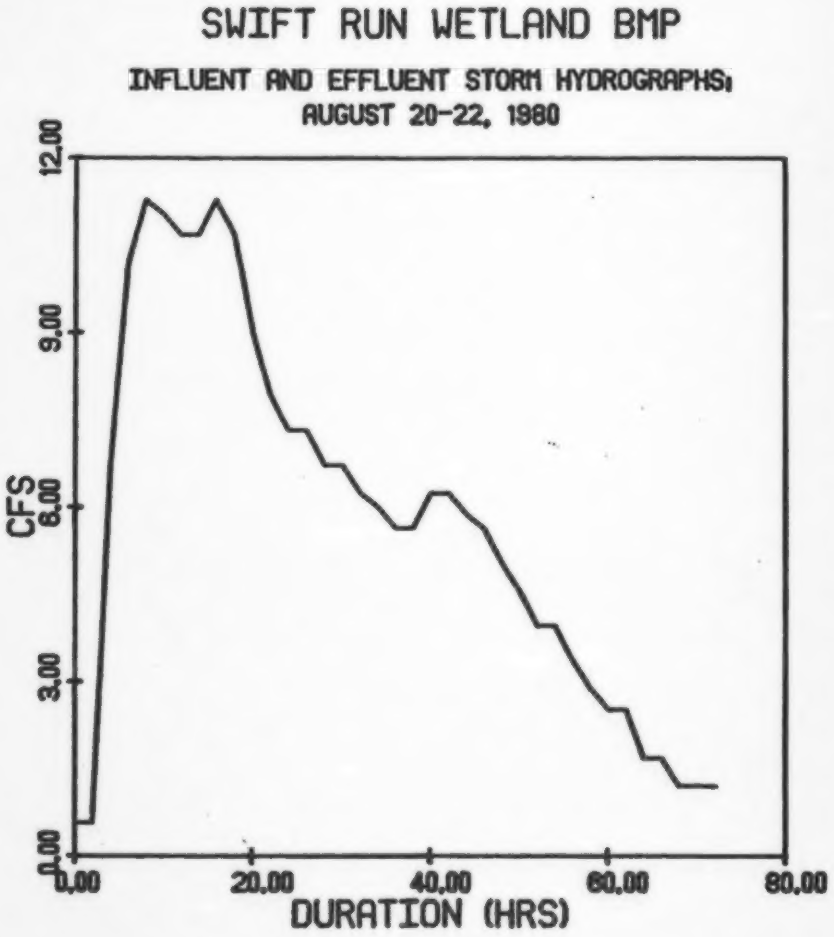
TABLE IV-27 (Continued)

Summary of Pollutant Loads
Swift Run Wetlands
Washtenaw County, Michigan

May 29, 1981 - June 1, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Inlet	554,000	900	18.8	0.69	<0.08	---	1.89	---	---	53
Outlet	554,000	1,080	4.1	1.7	<0.04	---	1.38	---	---	58
Pollutant Removed		-180	14.7	-1.0	0.04	---	0.51	---	---	(-5)
Percent of Inlet Retained		(-20)	78	(-145)	50	---	27	---	---	x

x = 0±10%
-- = parameter not monitored during this survey



SWIFT RUN WETLAND BMP

INFLUENT AND EFFLUENT STORM HYDROGRAPHS;
AUGUST 20-22, 1980

Figure IV-8

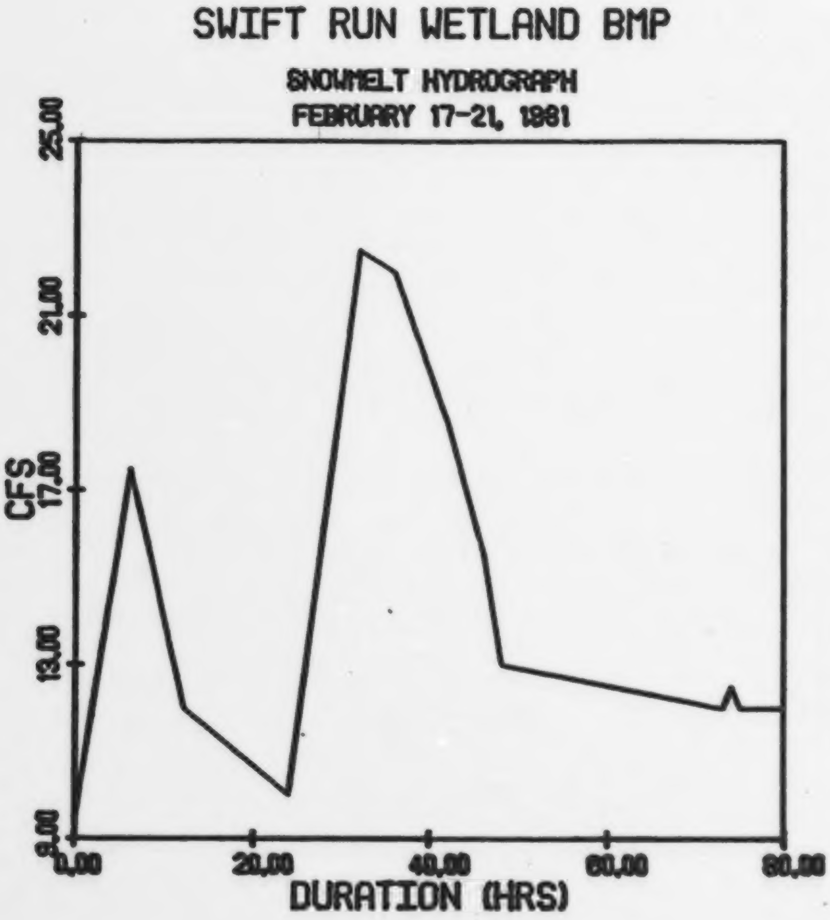

SWIFT RUN WETLAND BMP
SNOWMELT HYDROGRAPH
FEBRUARY 17-21, 1981
CFS
25.00
21.00
17.00
13.00
9.00
0.00
20.00
40.00
60.00
80.00
DURATION (HRS)

Figure IV-9

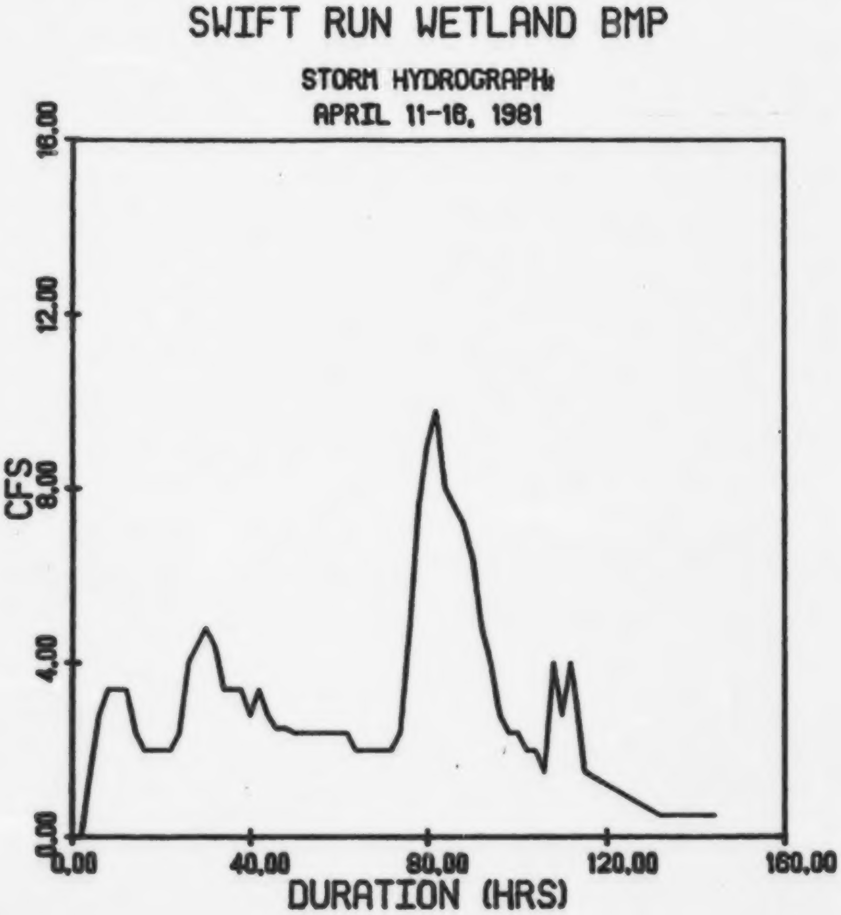

SWIFT RUN WETLAND BMP
STORM HYDROGRAPH:
APRIL 11-16, 1981
CFS
0.00
4.00
8.00
12.00
16.00
DURATION (HRS)
0.00
40.00
80.00
120.00
160.00

Figure IV-10

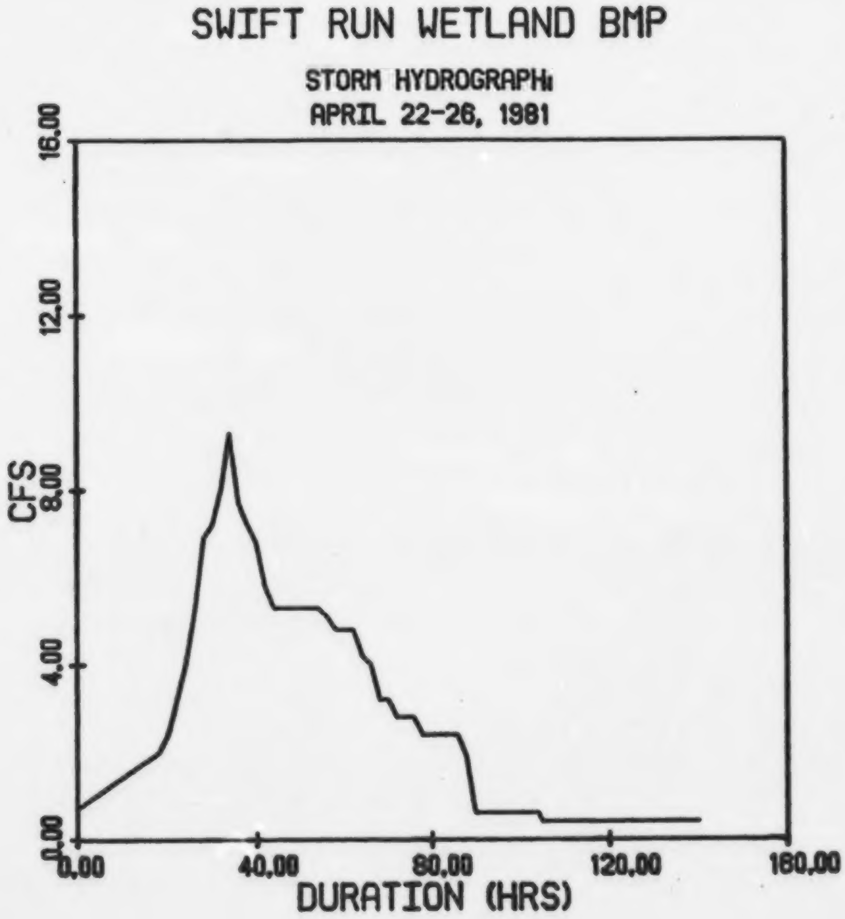

SWIFT RUN WETLAND BMP
STORM HYDROGRAPH:
APRIL 22-26, 1981
CFS
0.00
4.00
8.00
12.00
16.00
0.00
40.00
80.00
120.00
160.00
DURATION (HRS)

Figure IV-11

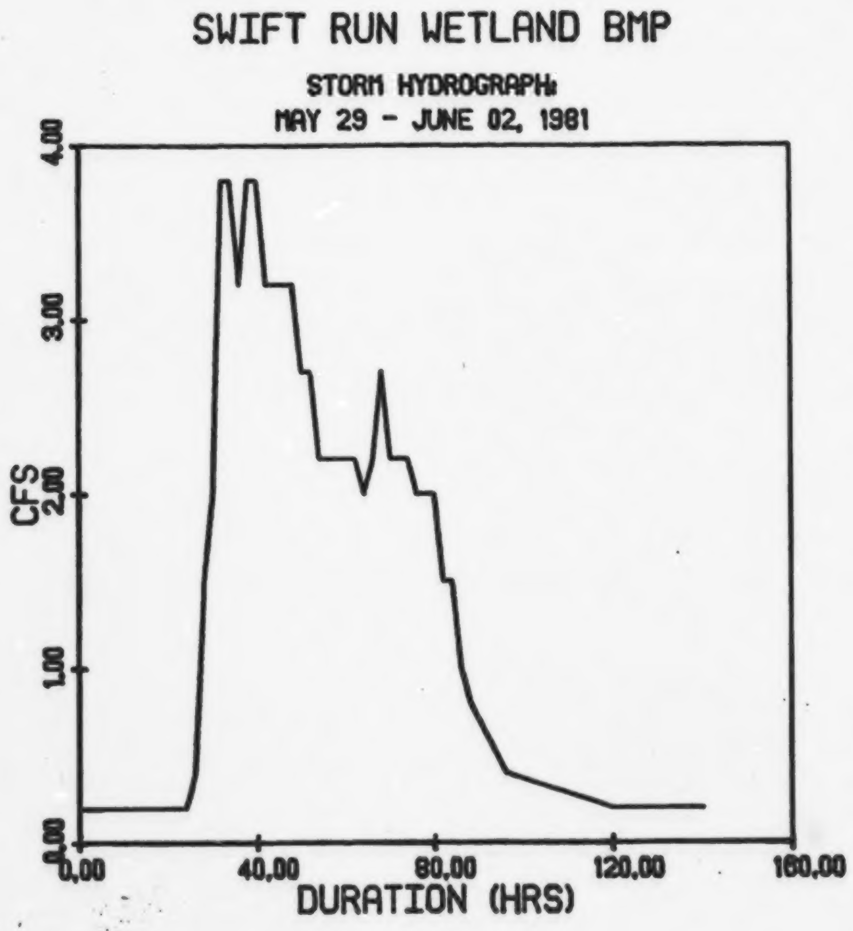

SWIFT RUN WETLAND BMP
STORM HYDROGRAPH:
MAY 29 - JUNE 02, 1981
CFS
0.00
1.00
2.00
3.00
4.00
0.00
40.00
80.00
120.00
160.00
DURATION (HRS)

Figure IV-12

Table IV-28
Swift Run Wetlands BMP
Runoff Coefficients

Date	Outlet
8/20/80	.16
4/11/81	.11
4/13/81	.26
4/22/81	.30
5/29/81	.21

The removal efficiency of the wetlands for most of the parameters monitored is very good. Total suspended solids removal efficiencies ranged from 76 to 93 percent for the five rain events. Total iron and lead removal efficiencies are also good with most being greater than 50 percent and as high as 87 percent. Again, the iron and lead removal efficiencies are associated with the total suspended solids removals. These metals are mostly present in the insoluble form and therefore would be expected to be influenced by sedimentation processes.

Nutrient removal efficiencies vary between storm events. Some total kjeldahl nitrogen is removed (20-30% efficiency) although most of the kjeldahl nitrogen is present in the soluble form. Usually one would expect the concentrations of these dissolved material to pass through the basin unchanged. However, aquatic plant life present in the wetlands is probably utilizing some of this available nitrogen accounting for the removals seen. Total phosphorus on the other hand is removed fairly consistently with efficiency ranges of 40-60%. One exception to this is seen on the May 29-June 1, 1981 event where no removal is experienced and in fact some material seems to be exported. During this event over 50 percent of the phosphorus present is in the soluble form in contrast to the other events where insoluble phosphorus is the major form present. During these events where insoluble phosphorus is the major form however, removal efficiencies ranging from 11-60 percent is experienced for soluble phosphorus. Again this can probably be attributed to aquatic plant utilization.

The relationships between nutrient inputs (i.e., phosphorus and nitrogen) and the wetland response is somewhat different than the effects of suspended solids, BOD_5 and metals. The response of the wetland is very dependent on the season of the year. During the warmer months when growth is occurring in the wetland, phosphorus and nitrogen will be utilized by the plants. This process will concentrate the nutrients in the wetland area during the warm months, and thus reduce the concentration of nutrients flowing out from the wetland. With the onset of winter, however, the plants die and the nutrients which have been accumulating begin to be released and flow from the wetland. Thus, during cold weather nutrient levels leaving the wetland will generally be higher than incoming water. During a sampling program for the Drain Commissioner 1977(2) this effect was noticed in the winter sampling period when nutrient concentrations were higher at the wetland discharge point than the general baseflow levels in the drain. The wetland response to nutrient inputs thus changes the timing of when the nutrients reach the river rather than actually removing or reducing a large portion of the total nutrient load. This change in timing can be a benefit to the river as the nutrient load is delivered during cold months when the impoundments along the river are also releasing their nutrient loads. Thus, the immediate impacts on the river of nutrients released from the wetland will be less during warm months when the greatest potential for severe water quality problems generally exists.

While much of the nutrient load will eventually reach the river, the wetland area may result in some actual reduction in nutrient load. Studies of wetland systems in Wisconsin have shown that phosphorus removal in the 0-30% range may be obtained due to permanent holding of phosphorus in the sediment. Some increasd removal of phosphorus can be obtained by harvesting the plant material, but the Wisconsin(3) studies indicated this represented only a small percentage (6%) of the phosphorus load. Some nitrogen reduction may also be obtained due to the reduction of nitrate by natural proceses. This reduction is dependent on specific conditions occurring in the sediment and requires an anaerobic environment to occur.

Particle size data indicates that there is a small shift in particle size distribution between the inlet and outlet stations (Tables IV-29-34). The outlet station has a greater percentage of smaller sizes reflecting the settling of the larger particles in the wetlands. This shift is very subtle primarily due to the fact that a larger than expected percentage of smaller particle sizes (<10 u) are entering the basin.

Although data is very limited it appears that before the upstream retention basin was completed a greater portion of the particles entering the wetlands were made up of particles greater than 10 microns. After the completion of

TABLE IV-29

PARTICLE SIZE DISTRIBUTION

LOCATION: Swift Run Wetlands   DATE: August 20-22, 1980

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.	Composite 4 Conc. mg/l	Composite 4 Load lb.
Inlet	>125	23	490	<2	<69	<2	<42		
	125-62.5	<2	<43	<2	<69	3	63		
	62.5-10	19	410	5	170	3	63		
	10-4	15	320	31	1,100	15	320		
	4-1	41	880	17	590	8	170		
	<1	22	470	5	170	6	130		
Outlet	>125	<10^{+}	<210	<10^{+}	<350	<10^{+}	<210	<10^{+o}	<210
	125-62.5								
	62.5-10								
	10-4								
	4-1								
	<1								

^{o} - Grab Sample.
$^{+}$ - TSS <10 mg/l.

TABLE IV-30

PARTICLE SIZE DISTRIBUTION

LOCATION: Swift Run Wetlands **DATE:** February 17-20, 1981
(Snow Melt)

	MICRON SIZE	Composite 1		Composite 2		Composite 4		Composite 6		Composite 8		Composite 9		Composite 10	
		Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.
Inlet	>125	<2	<17	<2	<26	<2	<53	<2	<23	<2	<45	<2	<100	<2	<140
	125-62.5	<2	<17	<2	<26	<2	<53	<2	<23	<2	<45	<2	<100	3	210
	62.5-10	7	61	10	130	<2	<53	10	110	11	250	8	420	9	630
	10-4	18	160	60	780	9	240	22	250	29	650	15	790	3	210
	4-1	21	180	80	1,000	19	510	60	670	42	940	14	740	18	1,300
	<1	5	44	20	260	30	800	38	430	39	870	10	530	5	350
Outlet	>125	3	26	<2	<26	<2	<53	<2	<23	<2	45	<2	<100	<2	<140
	125-62.5	<2	<17	<2	<26	<2	<53	<2	<23	<2	45	<2	<100	<2	<140
	62.5-10	<2	<17	6	78	5	130	<2	<23	3	67	3	160	5	350
	10-4	5	44	17	220	<2	<53	7	80	10	220	5	260	7	490
	4-1	<2	<17	22	290	26	700	26	300	38	850	16	840	12	840
	<1	4	35	14	180	23	610	11	130	40	890	9	470	5	350

TABLE IV-31

LOCATION: Swift Run Wetlands DATE: April 11-13, 1981

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.
Inlet	>125	<2	<15	<2	<22	<2	<33
	125-62.5	<2	<15	10	110	<2	<33
	62.5-10	5	39	10	110	<2	<33
	10-4	16	120	40	440	5	83
	4-1	37	280	53	580	21	350
	<1	27	210	47	510	10	170
Outlet	>125	<10*	<77	<2	<22	<2	<33
	125-62.5			<2	<22	<2	<33
	62.5-10			<2	<22	5	83
	10-4			7	76	3	50
	4-1			6	65	8	130
	<1			1	11	6	100

*TSS <10 mg/l

TABLE IV-32

PARTICLE SIZE DISTRIBUTION

LOCATION: Swift Run Wetlands DATE: April 13-17, 1981

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.	Composite 4 Conc. mg/l	Composite 4 Load lb.
Inlet	>125	<2	<43	<2	<47	<2	<21		
	125-62.5	<2	<43	<2	<47	<2	<21		
	62.5-10	10	220	10	240	<2	<21		
	10-4	50	1,100	<2	<47	13	140		
	4-1	87	1,900	47	1,100	18	190		
	<1	73	1,600	53	1,300	35	370		
Outlet	>125	<2	<43	<2	<47	<2	<21	<2	<6
	125-62.5	<2	<43	<2	<47	<2	<21	<2	<6
	62.5-10	<2	<43	<2	<47	<2	<21	<2	<6
	10-4	7	150	7	170	<2	<21	3	9
	4-1	8	170	20	470	20	210	7	22
	<1	6	130	27	640	22	230	17	53

TABLE IV-33

PARTICLE SIZE DISTRIBUTION

LOCATION: Swift Run Wetlands DATE: April 22-26, 1981

	MICRON SIZE	Composite 1		Composite 2		Composite 3		Composite 4°		Composite 5	
		Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.
Inlet	>125	<2	<39	<2	<35	<2	<37	<2	<29	<2	<10
	125-62.5	10	190	<2	<35	<2	<37	<2	<29	<2	<10
	62.5-10	10	190	<2	<35	4	73	<2	<29	3	15
	10-4	19	370	9	160	<2	<37	7	100	3	15
	4-1	48	930	16	280	15	275	7	100	7	35
	<1	33	640	14	250	13	240	4	58	2	10
Outlet	>125	<10*	<190	<2	<35	<2	<37	<2	<29	<2	<10
	125-62.5			<2	<35	<2	<37	<2	<29	<2	<10
	62.5-10			<2	<35	<2	<37	<2	<29	3	15
	10-4			<2	<35	<2	<37	4	58	<2	<10
	4-1			10	175	3	55	<2	<29	3	15
	<1			10	175	3	55	4	58	1	5

* TSS <10 mg/l.
° Grab

TABLE IV-34

PARTICLE SIZE DISTRIBUTION

LOCATION: Swift Run Wetlands   DATE: May 29, 1981 - June 1, 1981

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.
Inlet	>125	<2	<14	<2	<32	<2	<23
	125-62.5	<2	<14	<2	<32	<2	<23
	62.5-10	4	29	4	63	3	35
	10-4	7	50	<2	<32	3	35
	4-1	11	79	7	110	5	58
	<1	4	29	4	63	4	46
Outlet	>125	<2	<14	<2	<32	<2	<23
	125-62.5	<2	<14	<2	<32	<2	<23
	62.5-10	<2	<14	<2	<32	<2	<23
	10-4	<2	<14	<2	<32	<2	<23
	4-1	3	22	3	47	<2	<23
	<1	1	7	2	32	1	12

the retention basin (1981) the event data indicates that the particles entering the wetlands are now in the range of 10 u and below. This would suggest that some settling of the larger particles is now occurring in the upstream retention basin. However, a comparison of total suspended solids event mean concentrations for all of the events monitored at the wetlands show no clear difference between the 1980 and 1981 sampling years that would signal extensive sedimentation occurring in the upstream retention basin during 1981. Again it must be emphasized that the observations are based on only a very limited number of monitored events on the wetland and none on the upstream retention basin. It was not within the resources and scope of this project to monitor the upstream retention basin.

Fecal coliform results for the August 1980 storm survey shows high levels of coliform entering the wetlands and significantly lower concentrations exiting the wetlands. However, the April and May 1981 events show no significant coliform levels reduction between the inlet and outlet stations (Table IV-35). It should be noted that the coliform levels measured during the 1981 events are significantly lower than these measured during the one monitored 1980 event. Unfortunately not enough data is available to determine if these differences are in fact true conditions. Many variables exist that could account for the difference in these numbers including: time of year, water temperature and possible effect of the upstream retention basin. Additional sampling would have to be done throughout the summer and fall months to determine if indeed coliform concentrations are or are not affected by the wetlands and at what concentrations.

TABLE IV-35

Fecal Coliform/Fecal Streptococcus
Swift Run Wetlands

Station	Date/Time		Instantaneous Flow (cfs)	Fecal Coliform (CFU/100)	Fecal Streptococcus (CFU/100)	Fecal Coliform / Fecal Streptococcus
Inlet	8/21/80	13:45	4.7	100,000		
	8/21/80	15:00	5.0	120,000		
	8/21/80	16:00	5.2	24,000		
	8/22/80	10:30	2.1	6,900		
Outlet	8/21/80	11:00	4.7	<100		
	8/22/80	11:00	2.1	200		
Inlet	2/17/81	12:35	11.2	3,000		
	2/17/81	15:00	14.7	10,000		
	2/17/81	23:45	12.3	1,500		
	2/18/81	07:25	11.4	600		
	2/18/81	14:00	13.9	500		
	2/18/81	23:34	21.9	2,600	2,500	1.0
	2/19/81	07:10	17.8	3,200		
Outlet	2/17/81	12:20	11.1	1,000		
	2/17/81	14:45	14.7	4,000		
	2/17/81	22:15	14.0	630		
	2/18/81	07:00	11.6	1,800		
	2/18/81	14:00	13.8	1,000		
	2/18/81	23:30	21.9	3.200	2,100	1.5
	2/19/81	06:50	23.4	1,500		
Inlet	4/12/81	10:30	3.4	2,400		
	4/13/81	11:00	2.4	1,100		
	4/13/81	22:00	2.0	1,400		
	4/14/81	11:00	9.8	2,900		
Outlet	4/12/81	8:30	Av. 2.8	2,600		
	4/13/81	10:30	Av. 2.8	2,600		
	4/13/81	10:30	Av. 4.1	640		
	4/14/81	11:00	Av. 4.1	640		
Inlet	5/30/81	02:30	0.4	200		
	5/30/81	13:30	3.2	3,800		
	6/1/81	02:30	2.2	790		
	6/1/81	12:30	1.5	600		
Outlet	5/29/81	16:00	Av. 1.5	2,600		
	5/30/81	13:30	Av. 1.5	2,600		
	6/1/81	14:00	1.5	40		

Examination of the snow melt data shows that runoff during a snow melt period contributes large quantities of pollutants to the Swift Run Drainage Basin. The snow melt event summary data is presented in Table IV-23. The event occurred in February, 1981 and was the main snow melt of the winter. As demonstrated in the summary tables the wetlands are still capable of removing pollutants but at lower efficiency levels than achieved during the rain events. This can be attributed to several factors, first of which is the tremendous volume of water passing through the wetlands in a fairly short period of time. Although event mean concentrations (Table IV-36) for the snow melt show that individual parameter concentrations are not greater for the snow melt than for monitored rain events, tremendous loadings into the wetlands (monitored at the inlet station) are being generated due to the large runoff volumes. In addition, the wetlands at this time of year is not capable of utilizing any of the nutrients passing through in the runoff. Combining this with the fact that the settling time for the solids is reduced as indicated by the higher event mean concentrations measured at the outlet, the wetlands' removal efficiency mechanisms are definitely hindered during the snow melt period. Total suspended solids, BOD, COD, total and soluble kjeldahl nitrogen, total and soluble phosphorus and total iron event mean concentrations at the outlet are all considerably higher than those concentrations measured duing the rain events.

Discussion

As in the case of the Pittsfield-Ann Arbor retention basin, it was anticipated that sedimentation would be a

TABLE IV-36

Event Mean Concentrations

STATION: Swift Run Wetlands
Inlet
Outlet

DATE: Period of Record

Average Concentration		August 1980	February 1981 Snow Melt	April 11 1981	April 13 1981	April 22 1981	May 29 1981
TDS mg/l:	Inlet	298	189	430	320	307	370
	Outlet	235	230	387	366	294	321
TSS mg/l:		69	84	82	139	55	17
		4.9	46	15	30	10	4.2
Total Alkalinity mg/l:		136	64	132	140	147	136
		99	69	106	140	120	98
BOD mg/l:		2.9	8.2	2.0	2.0	2.0	4.9
		3.6	7.1	2.2	2.4	1.9	2.2
NO_3N mg/l:		1.6	0.70	0.78	1.2	0.92	0.27
		0.07	0.64	0.18	0.59	0.10	0.02
TKN mg/l:		0.97	1.7	1.0	1.3	1.0	1.3
		0.92	1.7	0.75	1.0	0.79	0.95
SKN mg/l:		0.80	1.1	0.68	0.85	0.88	0.72
		0.71	1.4	0.69	0.77	0.75	0.95
TP mg/l:		0.17	0.42	0.14	0.18	0.10	0.05
		0.09	0.26	0.63	0.09	0.04	0.07
SP mg/l:		0.06	0.28	0.03	0.05	0.03	0.02
		0.05	0.15	0.02	0.02	0.02	0.04

TDS - Total Dissolved Solids
TSS - Total Suspended Solids
BOD - Biological Oxygen Demand
NO_3N - Nitrate
TKN - Total Kjeldahl Nitrogen
SKN - Soluble Kjeldahl Nitrogen
TP - Total Phosphorus
SP - Soluble Phosphorus

TABLE IV-36 (Continued)

Event Mean Concentrations

STATION: Swift Run Wetlands   DATE: Period of Record
Inlet
Outlet

Average Concentration		August 1980	February 1981 Snow Melt	April 11 1981	April 13 1981	April 22 1981	May 29 1981
COD mg/l:	Inlet	33	42	28	26	33	26
	Outlet	32	44	32	29	28	31
T-FE mg/l:		1.5	2.3	1.1	1.9	1.3	0.54
		0.26	1.7	0.43	0.93	0.71	0.12
S-FE mg/l:		0.05	0.06	0.03	0.04	0.05	0.02
		<0.02	0.10	<0.02	0.04	<0.03	---
T-Pb mg/l:		0.02	0.01	0.01	0.01	<0.006	---
		<0.002	0.009	0.002	0.002	<0.001	<0.001
S-Pb mg/l:		0.0009	<0.0009	<0.001	<0.0009	---	---
		<0.0009	<0.001	<0.001	<0.0009	---	---
T-Zn mg/l:		0.04	0.06	---	---	---	0.05
		0.04	0.06	---	---	---	0.40
T-Cr mg/l:		0.009	---	---	---	---	---
		0.004	---	---	---	---	---
T-Cd mg/l:		0.0004	---	---	---	---	---
		<0.0002	---	---	---	---	---
G&O mg/l:		3.7	3.1	---	---	---	1.5
		1.3	2.6	---	---	---	1.7

COD - Chemical Oxygen Demand
T-FE - Total Iron
S-FE - Soluble Iron
T-Pb - Total Lead
S-Pb - Soluble Lead
T-Zn - Total Zinc
T-Cr - Total Chromium
T-Cd - Total Cadmium
G&O - Grease and Oil

-- parameter not monitored

primary mechanism of pollutant removal in the wetland. The basic discussion of factors affecting sedimentation presented earlier for the Pittsfield-Ann Arbor basin also apply to the wetland. One additional potential benefit of the wetland is the removal of soluble materials by the aquatic plants in the wetland.

Table IV-37 shows the theoretical minimum and average detention time for the various runoff events. Suspended solids concentrations and percent removal levels are also shown. The performance of the wetland was quite good for the runoff events.

The data in Table IV-37 is ranked by increasing minimum detention time (highest to lowest peak flow). As can be seen, there is a relationship between detention time and peak suspended solids levels and basin efficiency (with the exception of the 8-20-80 event). The much shorter detention times during the snow melt period resulted in higher solids levels at the outlet and a subsequent decrease in removal efficiency. Removal efficiency is higher for the longer detention periods, but appears to level off in the 80% range. There is little difference in the removal for minimum detention times beyond 20-24 hours or for average detention time beyond 48 hours.

As in the case of the Pittsfield-Ann Arbor basin, the peak suspended solids levels tend to follow the peak flows or minimum detention time. Event mean concentration was influenced by peak levels but not as severely as in the case of the retention basin. The ratio of peak flow to average flow was much smaller and more consistent for the wetland system. Two factors affecting the ratio of peak to average

TABLE IV-37

DETENTION TIME FOR MONITORED EVENTS
Swift Run Wetland

Date	Min. Detention Time (hrs.)	Ave. Detention Time (hrs.)	%TSS Removal	Peak TSS Conc. (mg/l)	Event Mean TSS Conc. (mg/l)
Snow Melt 1981	9.3	12	45	70	46
8-20-80	20	33	93	8	5
4-14-81	21	53	78	46	16
4-22-81	24	48	81	22	10
4-11-81	43	67	82	19	15
5-29-81	54	82	76	9	4

flow are the size of the basin and the upstream drainage system. The wetland is much larger than the retention basin in terms of the ratio of volume to typical runoff flow (i.e. longer detention times). This larger size dampens the peak flows and thus lowers the peak to average flow ratios. Dampening the peak flows results in a better settling condition in the basin and reduces the influence of the peak TSS concentrations. In addition, the upstream drainage system is all open channel and drains a relatively flat area. The peak flows are tempered by these physical conditions, thus reducing the stress on the wetland due to peak flow conditions.

Overall, the wetland provided good control of runoff pollutants for the monitored runoff events. The discharged water quality from the wetland was generally low in suspended solids (5-15 mg/l event mean), phosphorus and lead compared to normal urban runoff. The size of the basin provided this control over the entire size range of monitored rainfall events, all of which were higher than the mean rainfall event for this area. Thus, for typical rainfall events the wetland can be expected to produce an effluent of good water quality when compared with uncontrolled urban runoff or point source discharges. Its interesting to note that during all of the rainfall events the water from the wetland was below the tertiary treatment levels set for the Ann Arbor wastewater treatment plant (10 mg/l TSS, 10 mg/l BOD_5, <1 mg/l T-P).

Capital Cost - Swift Run Wetland

The Swift Run Wetland was a natural wetland which originally outlet via a natural drainage course (creek). The only construction required at the wetland was the building of a control structure at the outlet. The control structure was required to provide flood relief for downstream areas by utilizing the full capacity of the wetlands. Bank improvement around the new outlet structure was also required to prevent overland flooding at high stage levels.

Table IV-38 shows the capital costs associated with the wetland improvement project. The construction costs for the outlet are based on actual cost to build the structure plus bank improvements. As shown in Table IV-38, the land acquisition costs was the major item in the budget. The wetland area was part of very large lots on which homes had been built on the higher area of each lot. Thus, it was necessary to purchase land from several owners in order to control the wetland area. The payment to these land owners was the major cost of the project. Legal fees were also quite high for this project due to negotiations with some of the land owners. It was necessary to carry out condemnation proceedings to obtain a few parcels of land.

An interesting fact in the wetland project is that an original drainage improvement plan called for piping the runoff water through the wetland and thus eliminating the wetland. This piping would have cost at least 3 times as much as the wetland improvement project depending on the difficulty of laying pipe in the organic soils of the wetland. No flood protection would have been achieved in this case and large costs would have been incurred for enlarging sections of the downstream drain. Thus, total project cost would have been many times higher and no water

TABLE IV-38

CAPITAL COSTS
Swift Run Wetland

Construction Costs		
Outlet Structure		$33,750.00
	TOTAL	33,750.00
Land Acquisition		101,000.00
Engineering and Legal Fees		15,000.00
	TOTAL	149,750.00

NOTES: Only construction required was outlet. Wetland was naturally present.

Legal fees were high because of condemnation procedures need to aquire land.

quality benefits would have achieved. In this case, the less expensive option provided the best water quality control.

TRAVER CREEK RETENTION BASIN

The Traver Creek off-line detention basin is designed to provide flood protection for downstream developments and to provide a mean for water quality improvements. Construction of the basin and outlet structures started in 1980 but due to delays in construction was not completed until late in the summer of 1981. These delays forced modifications in the BMP sampling program. By March of 1981 the bypass structure was the only item that need to be completed. The drain had been rerouted by means of a temporary ditch directly into the basin. Since the bypass structure was not scheduled to be completed until the end of the summer of 1981, it was decided to monitor the basin as an on-line retention basin. No construction activity took place during the actual monitoring period (April-June). The objective of the evaluation of this basin is to determine the level of water quality improvement which can be expected from this type of on-line basin even though in this case the basin when complete will act as an off-line retention basin.

Data Collection

As described earlier, monitoring of the Traver Creek Retention Basin consisted of measuring flows and pollutant levels at the retention basins' inlet and outlet stations.

The inlet station consisted of a Stevens level recorder housed in a steel security box and anchored to a stilling well. A Manning discrete sampler equipped with a float switch activation assembly was used to collect discrete samples in 500 or 1000 ml bottles at fifteen or thirty minute intervals. This unit was secured under a 55-gallon steel drum. The outlet station consisted of a Stevens recorder and Manning automatic discrete sampler housed in a steel security box anchored to the cement outlet structure. Stage discharge curves were developed at each Station and were used to manually composite the discrete samples collected during a monitored event. Generally for the rainfall events, one to two composites were made to represent the major runoff portion of the event and one or two additional samples were composited to represent the tail portion of the curve and background conditions. Thus, a series of sequential composite samples were obtained to represent each runoff event.

Samples which were composited were either analyzed immediately by the laboratory or preserved by approved USEPA procedures. All compositing and preservation was performed in the laboratory as all stations were in close proximity to the offices. Analytical procedures followed approved methods. Quality control and quality assurance procedures are presented in the appendix.

Results

Five rain events were monitored during the Summer of 1981. Summaries of the pollutant loadings entering and leaving the basin are presented in Tables IV-39-43. These

TABLE IV-39

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

April 11-13, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Solub Kjeld Nitrog lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Traver Creek Retention Basin Inlet	729,000	22,500	1,600	9,700	44	43	37	28	3.7	1.1
Traver Creek Retention Basin Outlet	543,000	16,000	1,060	6,660	<35	28	15	12.0	1.4	<0.35
Pollutant Removed		6,500	540	3,040	9	15	22	16	2.3	0.75
Percent of Inlet Retained		29	34	31	>20	35	59	57	62	>68

TABLE IV-39 (Continued)

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

April 11-13, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Traver Creek Retention Basin Inlet	729,000	1,180	24	7.4	<0.06	<0.04	---	---	---	---
Traver Creek Retention Basin Outlet	543,000	592	18	0.98	<0.03	<0.03	---	---	---	---
Pollutant Removed		588	6	6.4	<0.03	<0.01	---	---	---	---
Percent of Inlet Retained		50	25	87	<50	<25	---	---	---	---

-- = parameter not monitored during this survey

TABLE IV-40

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

April 13-16, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Traver Creek Retention Basin Inlet	1,466,000	36,000	5,100	16,400	182	121	75	75	13.1	5.5
Traver Creek Retention Basin Outlet	1,456,000	38,700	5,450	17,600	<92	114	76	79	7.7	2.3
Pollutant Removed		(-2,700)	(-350)	(-1,200)	>90	7	(-1)	(-4)	5.4	3.2
Percent of Inlet Retained		x	x	x	49	x	x	x	41	58

x = 0±10%

TABLE IV-40 (Continued)

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

April 13-16, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Traver Creek Retention Basin Inlet	1,466,000	1,630	110	2.2	<0.14	<0.08	---	---	---	---
Traver Creek Retention Basin Outlet	1,456,000	1,990	111	2.8	<0.15	<0.09	---	---	---	---
Pollutant Removed		(-360)	(-1)	(-0.6)	(-0.1)	(-0.1)	---	---	---	---
Percent of Inlet Retained		(-22)	x	(-27)	x	x	---	---	---	---

x = 0±10%
-- = parameter not monitored during this survey

TABLE IV-41

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

April 22-27, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Traver Creek Retention Basin Inlet	1,581,000	37,700	3,620	18,100	208	121	99	63	8.9	<2.5
Traver Creek Retention Basin Outlet	1,359,000	31,400	3,040	15,240	258	65	71	50	6.7	0.99
Pollutant Removed		6,300	580	2,860	-50	56	28	13	2.2	1.51
Percent of Inlet Retained		17	16	16	(-24)	46	28	21	25	<60

TABLE IV-41 (Continued)

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

April 22-27, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Traver Creek Retention Basin Inlet	1,581,000	2,310	91	5.5	<0.15	---	---	---	---	---
Traver Creek Retention Basin Outlet	1,359,000	1,842	91	2.2	<0.11	---	---	---	---	---
Pollutant Removed		468	0	3.3	<0.04	---	---	---	---	---
Percent of Inlet Retained		20	x	60	<26	---	---	---	---	---

x = 0±10%
-- = parameter not monitored during this survey

TABLE IV-42

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

May 10-14, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Inlet	1,131,000	31,700	646	15,180	83	65	58	44	4.1	1.6
Outlet	1,063,000	30,200	888	13,040	121	42	46	29	2.4	0.67
Pollutant Removed		1,500	(-242)	2,140	(-38)	23	12	15	1.7	.93
Percent of Inlet Retained		x	(-37)	14	(-47)	35	21	34	41	58

x = 0±100

TABLE IV-42 (Continued)

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

May 10-14, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Inlet	1,131,000	1,947	28	3.4	<0.05	---	2.9	---	---	166
Outlet	1,063,000	1,335	23	1.5	<0.06	<0.06	2.6	1.3	<0.014	129
Pollutant Removed		612	5	1.9	(-0.01)		0.3			37
Percent of Inlet Retained		31	18	56	(-16)		10			22

— = parameter not monitored during this survey

TABLE IV-43

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

June 13-16, 1981

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Total Alkalinity lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Inlet	334,000	9,550	430	4,770	<40	26	22	17	2.0	1.0
Outlet	296,000	8,300	323	3,740	39	10	14	12	0.77	<0.21
Pollutant Removed		1,250	107	1,030	1	16	8	5	1.23	>0.79
Percent of Inlet Retained		13	25	21	x	61	36	29	62	>79

x = 0±10%

TABLE IV-43 (Continued)

Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

June 13-16, 1981

	Volume Cu. ft.	Chemical Oxygen Demand lbs.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Grease and Oil lbs.
Inlet	334,000	600	17	<1.1	<0.04	<0.019	0.73	0.13	<0.007	40
Outlet	296,000	374	7.7	0.75	<0.06	<0.017	0.57	0.23	<0.009	37
Pollutant Removed		226	9.3	<0.35	(-0.02)	<0.002	0.16	(-0.10)	(-0.002)	3
Percent of Inlet Retained		38	54	<32	<(-50)	<11	22	(-77)	(-29)	x

x = 0±10%

summary tables are based on total loadings entering and leaving the basin during the runoff period. The loadings presented include both baseflow conditions and loadings from the storm runoff period. Individual parameter values for each composite are presented in the separate data report. Generally, the first composite sample represents the beginning period of runoff, the second sample the middle portion of the storm and the third sample the tail portion of the curve and subsequent samples represent baseflow conditions. Sampling at the outlet station was continued for several days following a storm to insure water entering during the storm had passed through the basin. These composite cutoff times are only estimates and the actual composite cutoffs depend on the storm and runoff characteristics for each event.

Figures IV-13-16 show the runoff hydrographs for the inlet and outlet stations for the five monitored rain events. Overall comparison of the flow data and dissolved solids data collected at the two stations during all of the events shows a fair mass balance agreement between the inlet and outlet stations. In addition, runoff coefficients for the stations are fairly consistent for all of the events (Table IV-44).

Table IV-44
Traver Creek Retention Basin
Runoff Coefficients

Date	Inlet	Outlet
4/11/81	.08	.06
4/13/81	.22	.22
4/22/81	.21	.18
5/9/81	.16	.15
6/13/81	.03	.02

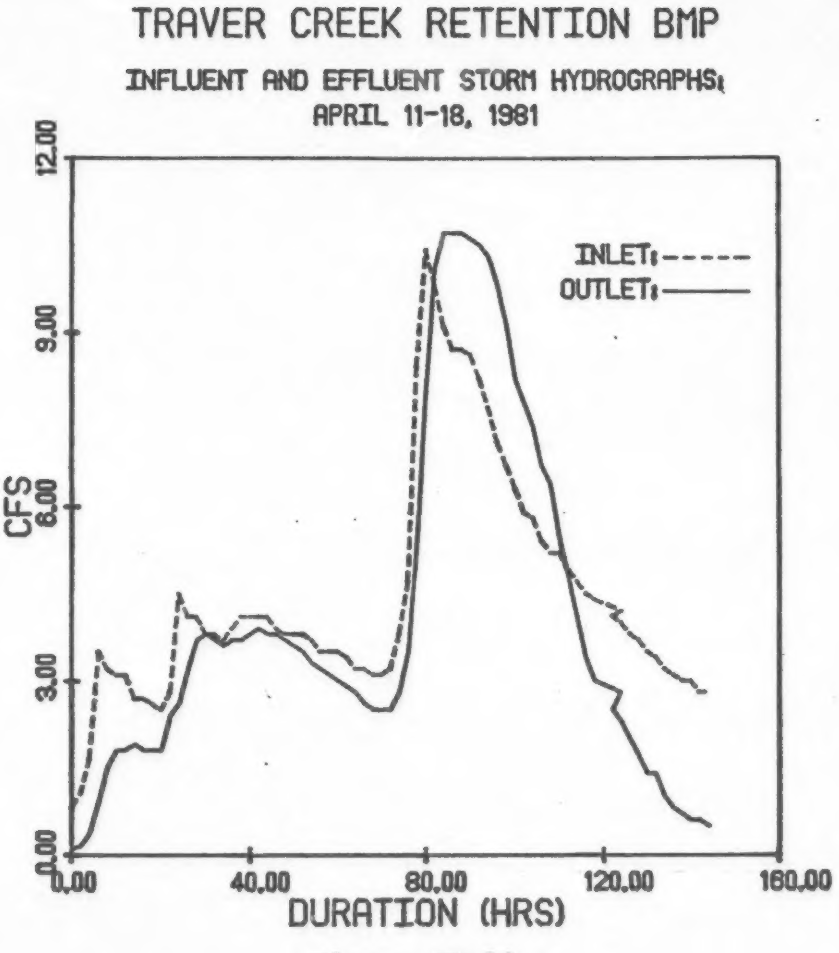
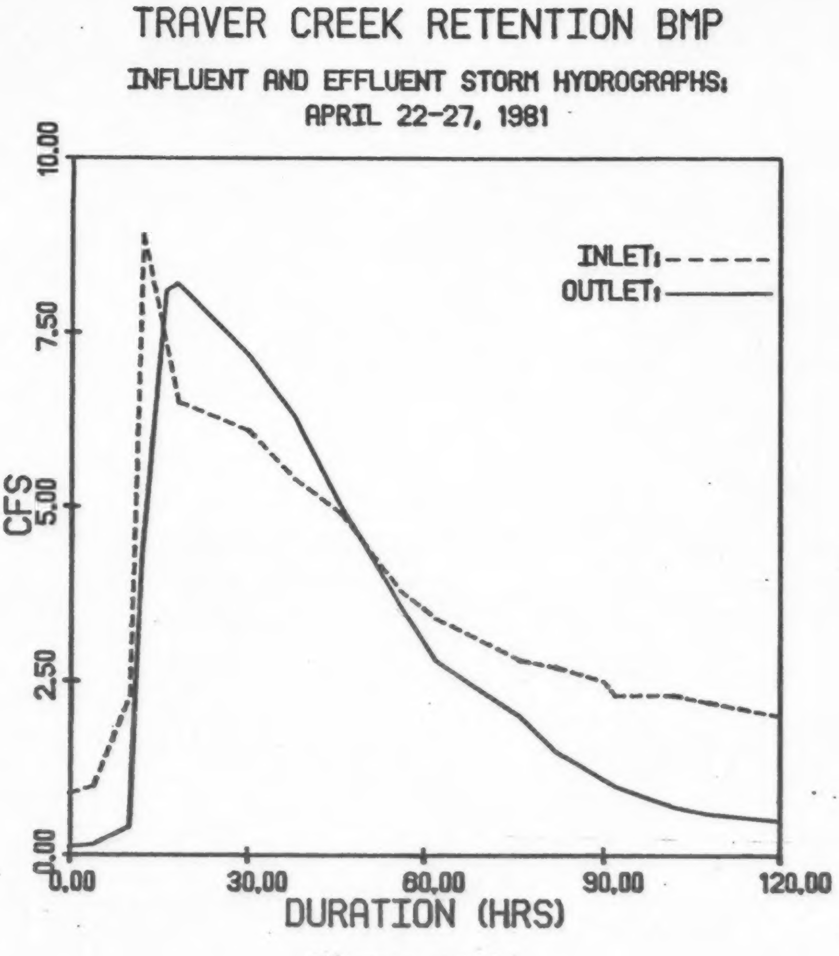

TRAVER CREEK RETENTION BMP
INFLUENT AND EFFLUENT STORM HYDROGRAPHS;
APRIL 11-18, 1981
INLET; - - - - -
OUTLET; ———
CFS
0.00
3.00
6.00
9.00
12.00
0.00
40.00
80.00
120.00
160.00
DURATION (HRS)

Figure IV-13


TRAVER CREEK RETENTION BMP

INFLUENT AND EFFLUENT STORM HYDROGRAPHS:
APRIL 22-27, 1981

Figure IV-14

TRAVER CREEK RETENTION BMP

INFLUENT AND EFFLUENT STORM HYDROGRAPHS:
MAY 10-14, 1981

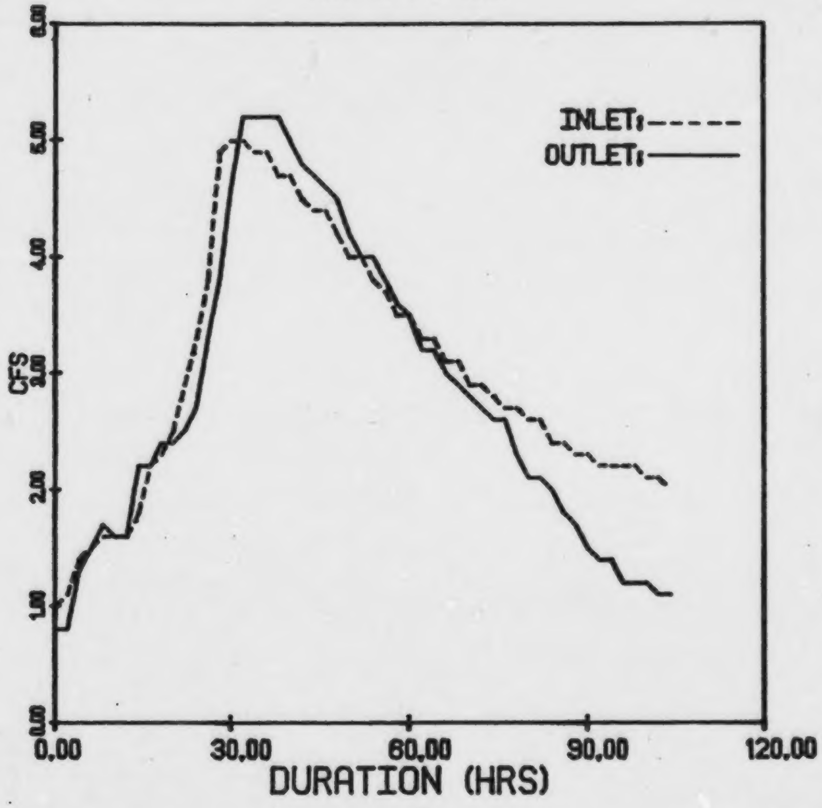
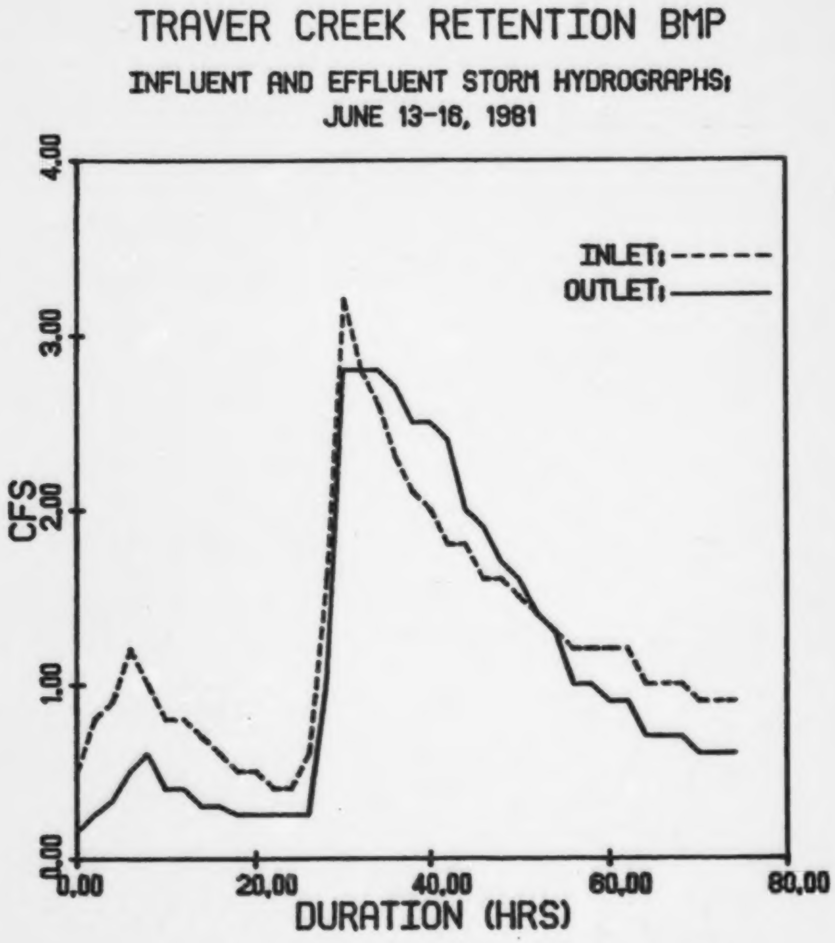


Figure IV-15



TRAVER CREEK RETENTION BMP

INFLUENT AND EFFLUENT STORM HYDROGRAPHS;
JUNE 13-16, 1981

Figure IV-16

The higher values experienced in the April 13-16 and April 22-27 events are probally due to the weather conditions that preceded these events. As seen in Chapter V, significant rain fell before each of these two monitored events. Ground conditions were saturated and conducive to runoff. Baseflow conditions were above normal at the beginning of the April 13-16 event but were down again for the beginning of the April 22-27 rain event.

The removal efficiency of the retention basin for most parameters monitored is very low. Total suspended solids removal efficiencies on a mass load basis are less than 25 percent for all of the monitored events. Suspended solids are actually exported from the basin during the May 9-14 rain event. The event mean concentrations (EMC) as shown in Table IV-45 show that for three events the total supsended solids inlet concentrations dropped very little, if any, at the outlet station. In addition the outlet concentrations exceeded the inlet concentrations for the remaining two monitored events indicating export of suspended solids from the basin. This export of suspended solids is probably due to the unstable retention basin bank conditions that existed during the study period. The retention basin was just recently constructed and the sod along the banks had not stabilized all of the side walls yet. Some side bank erosion problems were noticed during the monitoring periods.

Metals removals, which are usually associated with suspended solids removal and the sedimentation process are also very low for the five rain events. Some total iron removal is achieved in three of the five events. Removal efficiencies of 26 and 50 percent for total lead are measured for two out of the five events. The remaining

TABLE IV-45

Event Mean Concentrations

STATION: Traver Creek Retention Basin DATE: Period of Record
Inlet
Outlet

Average Concentration		April 11 1981	April 13 1981	April 22 1981	May 10 1981	June 13 1981
TDS mg/l:	Inlet	494	392	382	449	458
	Outlet	470	426	370	455	448
TSS mg/l:		35	54	36	9.1	21
		31	60	36	13	18
Total Alkalinity mg/l:		213	179	183	215	229
		196	194	180	197	200
BOD mg/l:		0.9	2.0	2.1	<1.1	<1.9
		<1.0	<1.0	3.0	5.7	2.1
NO_3N mg/l:		0.9	1.3	1.2	0.92	1.2
		0.83	1.2	0.76	0.63	0.55
TKN mg/l:		0.81	0.81	1.0	0.82	1.0
		0.43	0.83	0.84	0.69	0.76
SKN mg/l:		0.61	0.81	0.63	0.62	0.81
		0.35	0.86	0.59	0.44	0.63
TP mg/l:		0.08	0.14	0.09	0.05	0.09
		0.04	0.08	0.08	0.04	0.04
SP mg/l:		0.02	0.06	<0.02	0.02	0.04
		<0.01	0.02	0.01	0.01	<0.01

TDS - Total Dissolved Solids
TSS - Total Suspended Solids
BOD - Biological Oxygen Demand
NO_3N - Nitrate
TKN - Total Kjeldahl Nitrogen
SKN - Soluble Kjeldahl Nitrogen
TP - Total Phosphorus
SP - Soluble Phosphorus

TABLE IV-45 (Continued)

Event Mean Concentrations

STATION: Traver Creek Retention Basin DATE: Period of Record
Inlet
Outlet

Average Concentration		April 11 1981	April 13 1981	April 22 1981	May 10 1981	June 13 1981
COD mg/l:	Inlet	26	18	23	28	29
	Outlet	24	22	22	20	20
T-FE mg/l:		0.52	1.2	0.92	0.39	0.80
		0.53	1.18	1.07	0.34	0.42
S-FE mg/l:		0.16	0.01	0.05	0.04	<0.05
		0.03	0.03	0.03	0.02	0.04
T-Pb mg/l:		<0.001	<0.001	<0.001	<0.0007	0.001
		<0.0009	<0.002	<0.001	<0.0009	<0.003
S-Pb mg/l:		<0.0008	<0.0007	---	---	<0.0009
		<0.001	<0.001	---	<0.0009	<0.001
T-Zn mg/l:		---	---	---	0.04	0.03
		---	---	---	0.04	<0.03
T-Cr mg/l:		---	---	---	---	0.006
		---	---	---	0.02	0.01
T-Cd mg/l:		---	---	---	---	<0.0003
		---	---	---	<0.0002	0.0005
G&O mg/l:		---	---	---	2.3	1.9
		---	---	---	1.9	2.0

COD - Chemical Oxygen Demand
T-FE - Total Iron
S-FE - Soluble Iron
T-Pb - Total Lead
S-Pb - Soluble Lead
T-Zn - Total Zinc
T-Cr - Total Chromium
T-Cd - Total Cadmium
G&O - Grease and Oil

three events show no lead removal. In addition, the basin shows no removal capabilities for cadmium, chromium, and zinc.

Particle size data (Tables IV-46-50) indicates that there is not the characteristic downward shift in particle size groups between the inlet and outlet stations as seen in other retention basins. In fact, in some cases, greater percentages of larger particles are leaving the basin than had entered the basin. This indicates that either settling of the larger particles is not taking place in the basin or that some settling is occurring but erosion problems are introducing more sediment into the basin after the inlet station.

Biochemical oxygen demanding materials are lowered in only two of the events. However, the BOD concentrations at the inlet and outlet are very low to begin with and would have no deleterious impact on water quality of the drain. The basin did reduce some chemical oxygen demanding materials between the inlet and outlet with efficiencies ranging from 0-50 percent. Again these concentrations are also low and probably present no water quality problems.

Parameters that do show consistent removal efficiencies are nitrates (10-61 percent) and total phosphorus with an efficiency range of 25-62 percent. Over 50 percent of the phosphorus present is in the insoluble form which would indicate that sedimentation is the mechanism for removal. However, soluble phosphorus is also being removed with efficiencies ranging from 58-79 percent. Both soluble and insoluble kjeldahl nitrogen also show removal efficiencies with ranges from 0 to 59 percent.

TABLE IV-46

PARTICLE SIZE DISTRIBUTION

LOCATION: Traver Creek Retention Basin DATE: April 11-13,1981

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.
Inlet	>125	<2	<18	<2	<31	<2	<41
	125-62.5	<2	<18	<2	<31	<2	<41
	62.5-10	5	46	6	94	4	83
	10-4	14	127	9	141	5	103
	4-1	13	118	26	407	3	62
	<1	9	82	23	360	<2	<41
Outlet	>125	<2	<9	<2	<21	<2	<37
	125-62.5	<2	<9	<2	<21	<2	<37
	62.5-10	11	50	5	54	5	94
	10-4	7	32	NA	---	4	75
	4-1	17	77	21*	225	19	360
	<1	4	18	6	64	10	190

NA = Not Available
* 10-1 μ

TABLE IV-47

PARTICLE SIZE DISTRIBUTION

LOCATION: Traver Creek Retention Basin   DATE: April 13-16, 1981

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.
Inlet	>125	<2	<56	<2	<77	<2	<49
	125-62.5	6	170	<2	<77	<2	<49
	62.5-10	14	396	4	155	4	98
	10-4	24	678	6	232	<2	<49
	4-1	30	848	12	464	10	245
	<1	21	593	16	619	12	294
Outlet	>125	<2	<49	<2	<100	<2	<33
	125-62.5	3	74	6	300	4	67
	62.5-10	9	220	5	250	5	84
	10-4	41	1,000	10	500	<2	<33
	4-1	12	300	31	1,500	4	67
	<1	3	74	25	1,200	19	320

* TSS <10 mg/l.

TABLE IV-48

PARTICLE SIZE DISTRIBUTION

LOCATION: Traver Creek Retention Basin DATE: April 22-27, 1981

	MICRON SIZE	Composite 1 Conc. mg/1	Composite 1 Load lb.	Composite 2 Conc. mg/1	Composite 2 Load lb.	Composite 3 Conc. mg/1	Composite 3 Load lb.	Composite 4 Conc. mg/1	Composite 4 Load lb.	Composite 5 Conc. mg/1	Composite 5 Load lb.	Composite 6 Conc. mg/1	Composite 6 Load lb.	Composite 7 Conc. mg/1	Composite 7 Load lb.
Inlet	>125	<2	<36	<2	<34	<2	<45	<2	<25	<2	<33				
	125-62.5	<2	<36	<2	<34	<2	<45	<2	<25	<2	<33				
	62.5-10	20	363	6	101	7	158	4	50	<2	<33				
	10-4	31	563	7	118	4	90	3	38	<2	<33				
	4-1	65	1,180	9	152	3	68	<2	<25	<2	<33				
	<1	24	436	4	68	<2	<45	<2	<25	<2	<33				
Outlet	>125	10	190	<2	<37	<2	<44	<2	<12	<2°	<15	<2	<18	<2	<7
	125-62.5	40	750	3	56	<2	<44	<2	<12	<2	<15	<2	<18	<2	<7
	62.5-10	130	2,400	21	390	<2	<44	3	19	<2	<15	<2	<18	<2	<7
	10-4	37	690	8	150	4	87	4	25	4	30	<2	<18	5	17
	4-1	50	940	21	390	15	330	9	56	7	52	9	80	<2	<7
	<1	23	430	10	190	9	200	7	43	6	44	3	26	3	10

° Grab

TABLE IV-49

PARTICLE SIZE DISTRIBUTION

LOCATION: Traver Creek Retention Basin DATE: May 10-14, 1981

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.	Composite 4 Conc. mg/l	Composite 4 Load lb.	Composite 5 Conc. mg/l	Composite 5 Load lb.
Inlet	>125	<2	<8	<2	<29	<2	<54	<2	<27	<10*	<123
	125-62.5	<2	<8	<2	<29	<2	<54	<2	<27		
	62.5-10	3	11	9	129	5	134	<2	<27		
	10-4	<2	<8	3	43	<2	<54	3	40		
	4-1	3	11	3	43	6	161	<2	<27		
	<1	<2	<8	<2	<29	1	27	<2	<27		
Outlet	>125	<2	<6	<2	<29	<2	<52	<2	<30	<10*	<77
	125-62.5	<2	<6	<2	<29	<2	<52	<2	<30		
	62.5-10	<2	<6	6	90	<2	<52	<2	<30		
	10-4	4	12	6	90	5	130	4	60		
	4-1	3	9	5	70	4	100	3	45		
	<1	<2	<6	2	29	2	52	<2	<30		

* TSS <10 mg/l.

TABLE IV-50

PARTICLE SIZE DISTRIBUTION

LOCATION: Traver Creek Retention Basin   DATE: June 13-17, 1981

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.	Composite 3 Conc. mg/l	Composite 3 Load lb.	Composite 4 Conc. mg/l	Composite 4 Load lb.
Inlet	>125	<2	<3	<10*	<22	<2	<21	<10*	<63
	125-62.5	<2	<3			<2	<21		
	62.5-10	10	17			15	158		
	10-4	15	25			10	106		
	4-1	7	12			7	74		
	<1	2	3			1	10		
Outlet	>125	<2	<4	<2	23	<2	<10	<2	<6
	125-62.5	<2	<4	<2	23	<2	<10	<2	<6
	62.5-10	3	6	3	35	<2	<10	<2	<6
	10-4	<2	<4	3	35	3	15	5	16
	4-1	12	24	9	100	5	25	3	9
	<1	3	6	4	46	3	15	4	12

* TSS <10 mg/l.

Fecal coliform data collected during three rain events (Table IV-51) shows that the coliform levels entering the basin are fairly low and that some die off is experienced in the basin as exhibited by the lower outlet concentrations. The long detention time in this basin (50-60 hrs.) appears to provide sufficient time for significant die away to occur.

Discussion

The design of the Traver Creek basin provided good control of outlet flow and long detention times in the basin. Tables IV-52 shows the minimum and average detention time during runoff events and the associated suspended solids concentrations for these events. As shown in the table, long detention times are occurring in the basin and the peak flow (minimum detention) is well controlled for these size storm events. It would be expected, based on sedimentation theory and the other results of this study, that high removal efficiencies of suspended solids should be obtained in the basin. The data (Table IV-52) shows that this is not the case for suspended solids. Data for the phosphorus, nitrogen, and some metals (Tables IV-39-43) does show some removal of these materials. This type of performance (i.e. nutrient removal, no solids removal) is contrary to the findings of the other portions of the study.

The probable reasons for the relatively poor performance of the Traver Creek basin appears to be due to site specific conditions rather than design problems or more widespread difficulties with the basic BMP approach. A

TABLE IV-51

Fecal Coliform
Traver Creek Retention Basin

Station	Date/Time		Instantaneous Flow (cfs)	Fecal Coliform (CFU/100)
Inlet	4/12/81	10:30	3.7	500
	4/13/81	20:00	3.1	100
	4/14/81	08:00	10.4	23,000
	4/14/81	11:00	9.5	6,700
Outlet	4/12/81	10:30	3.6	1,000
	4/13/81	11:00	3.0	300
	4/13/81	22:00	2.4	100
	4/14/81	10:30	10.6	5,500
Inlet	5/10/81	21:25	2.5	600
	5/11/81	09:25	5.0	1,400
	5/13/81	10:45	2.6	700
Outlet	5/10/81	22:00	2.4	110
	5/11/81	10:00	5.2	380
	5/13/81	10:30	2.1	78
Inlet	6/13/81	10:20	0.8	26,000
	6/13/81	16:20	1.0	8,400
	6/14/81	00:25	0.5	2,000
	6/15/81	00:24	1.9	2,800
	6/15/81	09:25	1.5	1,400
Outlet	6/13/81	10:25	0.25	150
	6/13/81	15:25	0.58	140
	6/14/81	01:25	0.28	200
	6/15/81	00:55	2.5	820
	6/15/81	07:55	1.7	1,200

TABLE IV-52

DETENTION TIME FOR MONITORED EVENTS
Traver Creek Retention Basin

Date	Min. Detention Time (hrs.)	Ave. Detention Time (hrs.)	%TSS Removal	Peak TSS Conc. (mg/l)	Event Mean TSS (mg/l)
6-13-81	54	130	25	20	18
4-11-81	57	65	34	40	31
5-10-81	60	75	+	16	13
4-22-81	62	69	16	63	36
4-14-81	63	65	x	68	60

+ - export of material
x - 0± 10%

primary cause of the high outlet levels of suspended solids appears to be due to unstable bank conditions and subsequent erosion near the outlet structure. Due to delays in the construction schedule, the basin itself was not completed until the Fall of 1980. Sod had been placed on the banks to stabilize the soil at that time. It was anticipated that erosion would not be a significant problem in the spring. Unfortunatley, this does not appear to be the case especially during the April events.

In addition to the physical evidence that erosion problems existed, the data for other pollutants also tend to support this conclusion. Short cicuitry of water through the basin was considered a possible cause of the poor performance for removing suspended solids. It was difficult to conceive that short circuitry would be so significant given the very long theoretical detention times (50-70 hours). The fecal coliform data taken at various times during the event shows that inlet concentrations of coliform did not appear at the outlet in the same time frame as would occur in short circuitry situations. In addition, phosphorus and nitrogen showed overall reductions in levels, with outlet concentrations being lower than inlet levels. This data would indicate severe short circuiting is not occurring. The nutrient removal occurring in the absence of suspended solids reduction would also indicate that the suspended material being discharged was different in character than the material entering the basin. This would be the case if side bank errosion was occurring during April.

The banks were visually more stable during the May and June events, and the concentration of suspended solids leaving the basin dropped considerably (13-18 mg/l). The inlet level of suspended solids also was lower, however, during these events (9-21 mg/l). In general, the inlet levels of the pollutants being monitored were quite low during the study period. This condition is another site specific condition which appears to have affected the performance evaluation for the basin.

The land in the drainage area above the retention basin is not highly urbanized and the drainage system is a natural open creek type system. In general, all of the concentrations of the various parameters were lower in this drainage area when compared to the more urbanized and densely populated drainage districts such as Allen and Pittsfield-Ann Arbor Drains. It had been anticipated that suspended solids levels would be high in this area during larger storm events due to inputs from the agricultural areas. However, this was clearly not true for this drainage district. The input of relatively low concentrations of materials to the basin in the May and June events (after the banks appeared stable) resulted in little material being available for removal. This is a site specific condition which would not be the case in other urban areas or drainage systems.

The Traver Creek basin was built in anticipation of an increased level of development and runoff in the upstream area. The basin design considered the conditions which are expected after the area has been developed. Based on the results for the other BMP's studied, it is anticipated that this basin will be very effective in controlling the urban runoff. Unfortunately, given the conditions which occurred during the study, the monitoring data can not strongly support this opinion.

As stated in the discussion of the other BMP's, outlet control of peak flows and maintaining longer detention time at peak flows appears to be a major factor effecting basin performance. The Traver Basin is an example of a design which maximizes this condition. The data in Table IV-52 shows that minimum detention time does not vary greatly for the various storms yet the peak flows varied from 3 to 10 cfs. The restricted outlet was designed to become submerged with a slow rise in discharge rate as greater depths occur in the basin. The volume of the basin increases rapidly as the outlet flow rate increases. Thus the theoretical detention time remains fairly constant over a wide range of flows. This design should be a positive factor for basin performance, once the inlet flows increase and become more flashy due to urbanization. The outlet conditions are similar to a basin being studied in another NURP project. This other basin drains a fully urbanized area and the performance of the basin has been very good with removal levels of TSS in the 80-95% range.

Capital Cost - Traver Creek Retention Basin

The Traver Creek retention basin is located in a former gravel pit area. The location and topography necessitated a large amount of earth work in this area. In addition as stated in Chapter II, the basin area and outlet structures were designed for the 1 in 200 years storm due to requirements by the Michigan Highway Department. This design basis is for a much larger event than is normally considered for urban flood control. In addition, because

TABLE IV-53

CAPITAL COSTS
Beaver Creek Detention

Cost Description	Estimated Quantity	Unit Price	Total Amount
Clearing & Grubbing Dam & Diversion Areas only	L.S.		$15,000.00
Rough excavation of proposed basin w/ on-site disposal of excess material	93,000 c.y.	$1.19	$110,670.00
Excavation for dyke & diversion area	2,500 c.y.	2.00	5,000.00
Clay Embankment construction for dyke clay core	3,500 c.y.	1.25	4,375.00
Place & compact selected granular material from detention basin excavation on dyke	3,000 c.y.	1.30	3,900.00
Place available on site topsoil material on dyke	500 c.y.	1.75	875.00
Main creek & diversion ditch excavation & shaping incl. disposal of excess material	820 l.f.	2.50	2,050.00
30" CMP incl. anti-seep diaphrams	320 l.f.	30.00	9,600.00
Std. 4' dia. manhole (R-2)	1 ea.	1,000.00	1,000.00
30" Outlet headwall (R-1)	1 ea.	650.00	650.00
72" C-76 II concrete pipe with rubber gasket joints, concrete cradle & anti-seep collars	50 lf.	150.00	7,500.00
72" Outlet headwall (R-4)	1 ea.	4,000.00	4,000.00
Flow control structure at dyke (R-5) completed as specified	L.S.		17,500.00
Inlet structure in Basin (R-3) Complete as Specified	L.S.		12,000.00
Grouted Rip Rap (MDOT 6.1.07) including all grading & appurtenant work	120 s.y.	40.00	4,800.00
Plain Rip Rap (MDOT 6.01.09)	675 s.y.	20.00	13,500.00
Class "B" Sod in Place	2,700 s.y.	1.85	4,995.00
Seed, fert. & Mulch incl. fine grading	6.5 ac.	1,400.00	9,100.00
Stone Filter dam incl. installation, maintenance during const. & removal	1 ea.	3,000.00	3,000.00

TOTAL CONSTRUCTION	$229,515.00
ENGINEERING AND LEGAL FEES	23,000.00

NOTE: Land costs were zero as land was owned by the county.

the original design was for a dry off-line basin, a second control structure to maintain base flow in the creek was required. These factors should be carefully considered when reviewing the cost figures and will undoubtedly require adjustments if these costs are applied for other areas.

Table IV-53 shows the construction costs and other fees for the basin. The construction costs are based on the bid documents for the project. Engineering and legal fees are based on a percentage of the total project costs. No land acquisitions costs were required for this project as the land was owned by the government.

RUNOFF ORDINANCE

Background

Introduction

This section evaluates how the so-called runoff ordinance has been formulated and applied in one geographic area (Ann Arbor, Michigan), examines the philosophical and technical assumptions on which runoff ordinances are founded, and estimates how effective the runoff ordinance could be in limiting the pollutant load introduced to the reach of the Huron River (Michigan) being investigated.

In general, runoff ordinances represent an attempt by local units of government to prevent or minimize the adverse, off-site impacts of development or other land use changes. While local building codes and regulations have required the provision of adequate stormwater drainage facilities (catch basins, downspouts, pipe, open channels, etc.) within structures and in sites for many years, the intent of the ordinances under discussion is to go beyond the mere provision of stormwater drainage "hardware". The purpose of the ordinances of concern here is to influence the design and placement of such facilities so as to eliminate or reduce the hydraulic impact of the land use change on the receiving channel and downstream property. This category of ordinance is primarily concerned with the flow reduction during and after peak periods of storm events. A second category of ordinance also of interest is the one which attempts to regulate the pollution load contained in urban stormwater runoff. Examples of the ordinance for flow regulation are relatively unusual, but examples of the ordinance for water quality regulation are extremely rare. We are fortunate to have an example of each category of ordinance currently in effect in the county where this project has been conducted, and each has been carefully examined and compared.

It should be noted in passing that the adoption and implementation of these ordinances represents a significant change in public policy for stormwater facilities and for environmental protection. Heretofore, stormwater drainage facilities were designed so as to remove the storm flow as rapidly as possible from the land surface, and the construction and/or modification required in the receiving waterways was usually financed by at-large ad valorum property taxes. Ordinances regulating flow, in contrast, require some of the stormflow to be held on-site, for varying periods of time, and also require the developing party to finance the increased cost for such on-site improvements.

Where ordinances regulating the quality of stormwater runoff are adopted and applied, public policy has been changed to recognize the pollution impact of stormwater on local water resources. Ordinances regulating quality are an explicit attempt to prevent or reduce the pollution impacts associated with land use changes. Such ordinances can be applied in existing developed areas, with some difficulties discussed below, but have their greatest potential application in areas undergoing rapid urbanization. In such urbanizing areas, ordinances of both kinds can be a powerful preventive tool which local units of government can use to guide development. Ordinances regulating runoff quality also explicitly recognize that those initiating land use changes should also be responsible for the cost of preventing adverse environmental impacts.

Feasibility and Practicability of Runoff-Regulating Ordinances

In studies carried out by the Southeast Michigan Council of Governments (SEMCOG) during the 208 planning process, the role of stormwater ordinances which affect water quantity and/or quality in this region were considered and found to be of great importance. One report issued by the 208 program indicated not only that stormwater ordinances adopted by local units of government were permitted by state law, but also that such ordinances were an appropriate water quality management alternatives for the region.

Ordinances must be approved and adopted by the elected, legislative body of a local unit of government. The stormwater ordinance is only one aspect of urban physical development influenced by rules, guidelines, and standards embodied in design and construction ordinances. The ability of a local unit of government to determine the composition and pattern of land use and minimum construction standards is a well-established perogative in Michigan statutes and case-law. Using this institution and body of law to regulate the rate and quality of urban stormwater is, however, a recent occurrence. All statutory procedural requirements for adopting an ordinance must be followed, including public notice, hearings, and the opportunity to offer public comment on the proposed language of the ordinance. In the case of the City of Ann Arbor's ordinance, which regulates only the flow aspects of urban stormwater, the administration of the adopted ordinance is the responsibility of the City Utilities Department.

Another public agency in the County which influences the design of urban stormwater drainage facilities is the Office of the County Drain Commissioner. The involvement of this agency is described below.

The practicability of regulating the quality of urban stormwater runoff via ordinances is essentially still being determined. The legal authority exists, the cooperation of local government is probable and in some cases evident, but the most effective and efficient method of accomplishing urban stormwater quality management using ordinances, for a given region, remains to be demonstrated.

Regulation of Stormwater Runoff During Construction

Since 1972 the State of Michigan has required most development which is greater than one acre or within 500 feet of a lake or stream to comply with Public Law 347 of 1972, the Soil Erosion and Sedimentation Control Act. This law is administered at the county level by the county department selected by the Board of Commissioners. Implementation requires that a plan to prevent soil erosion from the construction site be prepared, submitted, reviewed, and approved, and a permit issued prior to construction. Fees to perform the review and inspect the site are collected. Performance bonds can be required and used if the plan is not followed. Inspections during construction usually occur to assure that the plan is carried out. A final inspection ascertains that the condition of the site conforms with the plan and a certificate of compliance is issued.

The law applies only to activity during construction and does not address runoff quality or quantity after the development is in place. The only parameter of concern is sediment, and there is no requirement that runoff generated during storm events be monitored to determine whether the soil erosion prevention measures are in fact successful. The law requires that a zero-discharge standard for sediment be applied. The flow rate and other aspects of the stormwater runoff from the site are not within the purview of this law. It must be said though that the law has not presented an unreasonable burden and has vastly reduced the volume of sediment generated and released to the State's waters during construction. Requirements under the law are, of course, in addition to what may be required by the City runoff ordinance or the County stormwater drainage rules for subdivisions which are discussed next.

Local Ordinance to Regulate the Rate of Peak Discharge of Urban Stormwater: An example

The ordinance adopted by the Ann Arbor City Council in 1978 recognizes that, relative to undeveloped conditions, urban development increases impervious surfaces, and, therefore, the volume of stormwater to be discharged. The ordinance requires that the peak rate of discharge from the developed site not exceed the peak rate from the undeveloped site. The quality of the stormwater is not addressed by the ordinance. This requirement has resulted in creative hydraulics, spirited technical and policy discussions at public hearings, and many small retention areas on recently developed property.

Chronology

1. November, 1977 - An ordinance requiring "pre-planned flooding areas" is introducted for it's first reading at the City Council.
2. December, 1977 - The proposed ordinance is adopted and put into effect by the City Council. The "1977 Ordinance" and all subsequent revisions of the ordinance, applies only to flow rates which are prescribed. The 1977 ordinance provides that the rate of stormwater runoff from a building site shall not exceed the rate which would have occurred from the site

in an undeveloped condition as a result of a storm with a 10 year return frequency." The rational method (Q=CiA) is prescribed as the method for calculating storm runoff. Areas of building sites devoted to complying with this ordinance must be shown on the grading plans which must be submitted. Sites smaller than 10,000 square feet (approximately one-quarter acre) may be exempted by the City Administrator. In addition to the rate of runoff flow requirement, "capacity must be provided for the temporary retention of storm water runoff from a projected 100-year, 12-hour duration storm." Methods for providing such "pre-planned flooding areas" are defined. The intensity factor (i) in the Rational Method (Q=CiA) is defined to be "4.5 inches per hour rainfall intensity," so-called wet-retention areas, those which contain water between storm events, are allowed only if approved by the City Administrator. In all other cases the retention areas shall discharge from the bottom and be dewatered within [illegible] hours, even if pumps are required to complete the dewatering within [illegible] hours.

3. December, 1977 - May, 1978 - Numerous development proposals are designed and reviewed by the City to comply with the ordinance. The requirements of the ordinance outlined above are subject to different interpretations by the developers and administrators.

4. May 1978 - City Council repeals the 1977 ordinance, and establishes a Stormwater Retention Committee to revise the ordinance. Discussions of the needed changes occur with local private consulting engineers. The City Utilities Department also communicates its perspective

on the 1977 ordinance;

5. October 1978 - The first draft of the revised ordinance is introduced at first reading.

6. November 1978 - The second draft, slightly modified from October 1978 draft, is adopted and put into effect by the City Council.

Comparison of 1978 and 1977 Ordinances

The significant differences between the 1978 and 1977 ordinances center on the volume of runoff water to be retained, the maximum permitted rate of discharge from the retention facility, and how the ordinance is applied in already developed areas.

One consistent feature of the two ordinances is that some portion of the increased storm runoff volume resulting from development is to be stored on the site. The amount [illegible] in either ordinance. The 1978 ordinance tends to require that less volume of storage be provided on-site. This means less earth moving during construction, less area devoted to retention facilities, and corresponding lower site development costs.

The 1978 ordinance defines the volume of stormwater runoff to be temporarily stored on site as the differnece between the accumulation from the developed site 100-year, 12-hour duration storm and the undeveloped site 10-year, 12-hour duration storm. This is the difference between 4.3

inches in the former case, and 3.1 inches in the latter. The 1977 ordinance did not allow the "credit" for the volume from the 10-year, 12-hour undeveloped site.

The maximum rate of discharge from the site in the 1978 ordinance is still limited to the "rate of stormwater dicharge from the undeveloped site from a 10-year rainfall." However, the method of calculating that maximum rate is changed to incorporate the time of concentration concept. The intensity value, i, of CiA is now defined by 170/t+23 where t is the time of concentration. The 1977 version of the ordinance used a constant 4.5 inches/hour. The 1978 ordinance provides that the maximum rate of discharge from a completely unimproved site is presumed to be no greater than 0.2 cfs/acre. Higher rates will be accepted if a case can be made for it based on site conditions. By being able to use the time of concentration, the ordinance places less of a burden on the development of large sites. Indeed, large sites under the 1978 ordinance need to accomodate a smaller volume than in the 1977 ordinance and can, in some circumstances, use a maximum discharge rate higher than that required by the 1977 ordinance.

City staff expressed deep concern about the definition of the area to be considered when selecting a time of concentration. No definition, in fact, appears in the ordinance, and thus the question of off-site runoff which flows over the site is unresolved. Likewise, whether one is to include pervious cover on the site or only impervious cover in estimating the time of concentration is unclear and has resulted in lengthy and unresolved disputes between developers and those administering the ordinance.

The minimum scale of the project which must comply with the 1978 ordinance is 15,000 square feet of "impervious improvements", whereas the 1977 version exempted "sites" smaller than 10,000 square feet. The effect is to reduce the number of sites which would have to install detention facilities. As currently written the critical aspect is the extent of impervious surface, rather than the extent of the total site being altered. As there is no definition of the C values which constitute "impervious improvements", considerable judgment must be exercised to determine whether a project is subject to the ordinance.

The 15,000 square feet of "impervious improvements" also has an impact on the extent to which the ordinance can be applied to the redevelopment of existing built-up areas. In general, such redevelopment tends not to exceed 15,000 square feet of "impervious improvements" and is not required, therefore, to provide on-site detention. Numerous small-scale redevelopments or improvement projects could induce a greater peak flow. While the increased flow generated from a single parcel may not be significant, the cumulative effect over time could result in sizeable peak volumes being added to lateral lines. This possibility is minimized to some extent by the 1978 ordinance: "If subsequent cumulative improvements result in impervious surfaces greater than 15,000 square feet, retention facilities must be installed for all improvements built after December 1, 1978."

There are additional aspects of flow rate-limiting ordinances which neither revision of the ordinance addresses. The following remarks are intended to be constructive and objective, and in no way should they detract from the commendable effort expended to better manage urban stormwater runoff. First, it would appear that the structures installed to comply with the ordinance could require routine maintenance over a long period of time. This would include such actions as checking the outlet for debris, (re)vegetation and bank stabilization, and removing the sediment which will be captured over time and reduce the available storage. No explicit provision is contained in the ordinance for assigning maintenance responsibility. The worth of the detention areas, however, depends upon their performing as designed, and maintenance appears to be crucial in their long-term performance. This point leads to an even more general observation that the ordinance forecloses any consideration of off-site storage of stormwater runoff. Collection and storage of stormwater runoff from many development sites would likely result in longer detention/retention areas and may well be more difficult to administer and finance. On the other hand, an area-wide approach to stormwater detention/retention could provide an equivalent degree of peak flow modification at a lower cost. Only one outlet structure would have to be built, for example, rather than several. And more intense development would be permitted on land planned, zoned, and priced for commercial and residential uses. As well, by having a larger single area devoted or dedicated to stormwater retention/detention, it is more feasible to provide water quality benefits in the overall design.

Finally, the ordinance is silent on the question of whether projects initiated by the public sector must comply with the ordinance. New housing projects and public roads are examples of projects which result in great amounts of runoff, and are undertaken by governments, Re-building or resurfacing public roads is an especially good candidate for runoff ordinances, but compliance would probably be difficult and expensive.

County Rules Controlling the Quality of Stormwater Runoff From Proposed Subdivisions

In order to present an accurate picture of the local regulations addressing urban stormwater, as well as to recognize an innovative approach to controlling the quality of urban stormwater runoff before a problem exists, the following summary of the Washtenaw County Drain Commissioner's Rules for subdivisions is included. Examining these rules will also lend insight into how existing ordinances regulating the rate of stormwater discharge can be modified to address the quality of stormwater as well.

It should be emphasized that these rules were adopted in September 1979, and were developed with the advice and participation of the local, private, engineering consultants who are now following them.

Michigan law requires the Drain Commissioner in each county to review and approve the drainage provided in all new subdivisions. Several other county and state agencies are also empowered to review and approve proposed subdivisions for aspects within their purview. The extent and rigor of the required review varies greatly. In Washtenaw County the Drain Commissioner has adopted a set of rules which establish the procedure and design standards to be applied during the review. The rules are a comprehensive and integrated effort to prevent many of the adverse impacts on water resources which have occurred because of poorly developed subdivisions in the past. Both the peak rate and the quality of discharge of stormwater from a proposed subdivision are regulated by the rules. There are three major procedural steps in the review. The first, the preliminary plat, requires the proprietor to submit information about the site's surface water features: existing water courses, flood plains, contours, soil borings, the proposed drainage boundary, relationship to the existing drainage pattern, upstream area's zoning, and the upstream area's calculated current and fully developed runoff. At this point in the process the general drainage scheme for the subdivision should be proposed, and should recognize that;

1. retention will be required,

2. The retention will be on-site,

3. The amount of storage volume required will be calculated using design criteria which permit outflow to occur while the retention areas is filling. The 100-year storm is the "design" storm.

4. The maximum rate of stormwater discharge from the subdivision's outlet may not exceed that which would occur from the 10-year storm if the site were totally undeveloped. (If that 10-year undeveloped site runoff rate is greater than 0.2 cfs/acre, data must be submitted to demonstrate that the outlet will pass the calculated flow.) (Time of concentration is assumed to be zero.)

5. Sediment in the runoff from paved or gravel roads equal to or greater than 100 microns shall be removed prior to the runoff leaving the site.

These rules are the most thorough attempt at a preventive, planning approach to urban stormwater known at this time by the authors, and the following observations are intended to better focus the technical issues which must be examined in this kind of urban stormwater BMP.

The requirement for retention within the project boundaries, while less restrictive here than in the City's Ordinance, could be, nevertheless, a constraint in evaluating alternative ways of accomodating either or both the maximum rate of the quality standard. This could be true on small subdivisions sites, or on ones with special or unique topographic features.

It is not clear that using the volume from the 100-year event necessarily provides signficantly greater water quality benefits over those which would occur if the volume from only the 50-year, or 25-year, or 10-year storm were treated. The reasons for exempting runoff from areas other than road surfaces are not clear. Parking areas in particular would seem to be important "sources"; other impervious areas also contribute flow and, therefore, a pollution load. Selecting sediment as the single parameter is reasonable, based on the current level of knowledge and on 208 data for the region, but it could be irrelevant if a significant portion of the annual pollutant load is in the dissolved form. Sediment would, of course, still be trapped, but sediment may not be the pollutant of greatest concern. Further work documenting the pollutants associated with different particle sizes may require the 100 micron standard to be raised or lowered. The notion of a single, uniform particle size-standard may require modification because it does not, by itself, consider either the nature and area of the drainage district contributing runoff, or it is sensitive to the quality of the receiving water. One hundred (100) microns may be more stringent than is required in one case, but not stringent enough in another.

Monitoring how well the detention/retention facilities perform with respect to water quality is an essential method of assuring that the design is sufficient, and may have to occur in order to demonstrate that the devices do achieve the desired level of performance. And, finally, there is again the question of routine maintenance. Where the quality of runoff is so clearly an objective, it seems essential that the trapped sediment be routinely removed. The very serious concern here is that the detention facilities may, in effect, concentrate a sediment load from one or several small events and be unable to retain the trapped sediment following a very intense large event. Being able to plan and design retention/detention basins which are effective sediment traps seems to suggest a level of maintenace and cleaning that is higher than what is presently considered necessary.

The results from the study of the retention basin and wetland BMP's begin to answer some of the questions regarding the potential effectiveness of this ordinance. It is quite clear that water quality improvement in the areas of suspended solids, phosphorus, and heavy metals can be achieved in flood control retention basins. The effectiveness of the basin is highly dependent on the control of the peak flow and the detention time. Blending the wetland and retention basin data together a first cut estimate of the performance for suspended solids as a function of minimum detention time can be made. Assuming similar inlet conditions (i.e. concentrations, particle size) minimum detention times of 3 to 10 hours will result in removal efficiencies in the 10 to 50 percent range. Minimum detention times in the 16 to 24 hour range will result in efficiencies for suspended solids in the 70 to 90 percent range. Using these types of values coupled with site specific runoff information plus the rainfall statistics for the area will allow for estimating a particular basins performance. It was also apparent from this study that the basin design characteritics are important in determining basin performance. Thus, basins designed to meet the flood control ordinance should also account for the potential of gaining water quality improvement through proper design.

The 100 micron particle size stated for control in the ordinance was a first attempt to highlight the importance of designing basins to enhance sedimentation. The results of this study indicate that this value of 100 microns is too large to effect a major impact on stormwater quality. The major fraction of the suspended material is smaller than 100 microns. Based on the new data base, consideration of lowering this value should be undertaken. Lowering this target value to 60 micron under peak 10 year flow conditions or 1 year peak flow conditions would further emphasis the importance of the dual role for a basin, both flood and water quality control. Lowering the target under peak load conditions would effectively result in average storm events during the year being controlled to lower levels on the average assuming proper outlet design.

The flood control ordinances do not specify the type of basin (wet or dry) or other methods to be used in control of the peak discharge. The City ordinance emphasizes dry basins by requiring permission to sue a wet retention basin. The effectiveness of a dry basin in controlling pollutant loads has not been defined as all of the basins studied in this report were wet type basins. The NURP project in general, however, does include studies of dry basins. The results of these other studies will be very important in determining if a basin type should be specified in the ordinance. Preliminary indications at the NURP review meetings suggest that dry detention basins are not very effective in controlling water quality while wet basins are effective. Once this type of information is available a review of the ordinances should be undertaken.

During this project, a request was made by the groups working on the public participation program for a discussion of design factors which could influence flood control basin design. A copy of this document is in the Appendix. It should be noted that this document was written without any available data on dry detention basins. Therefore, some of the comments on the dry basins may not be appropriate depending on the findings of the other NURP projects.

REFERENCES

1. Controlling Urban Stormwater Runoff In Washtenaw County, Huron River Watershed Council and Ecology Center of Ann Arbor, Ann Arbor, Michigan, 1981.

2. Existing Wet and Dry Weather Quality Conditions and Alternatives for Reducing Wet Weather, Urban Nonpoint Source Water Pollution Loadings, E.W. Say and Associates, Inc., Ann Arbor, Michigan, 1978.

3. Lee G.F., E. Bentley, and R. Amundson, 1979. Effect of Marshes on Water Quality. Water Chemistry laboratory, Madison, Wisconsin.

CHAPTER V. SOURCES

A. INTRODUCTION

This chapter presents information on the major sources of non-point source pollutants in the study area. Atmospheric contributions and land use runoff sources are the two major pollutant contributors to the Argo Dam-Geddes Dam reach of the Huron River. There are no major point source discharges within this area. (See Chapter VI for more detail).

B. PRECIPITATION

As described earlier, rainfall intensity and volume were measured by the use of a 7-day recording weighing-type gauge that measures the quantity and intensity of rainfall by accumulating weight of rainfall collected over time. In addition, manual gauges were used throughout the study area to measure total rain volume in order to detect any variations in rainfall volumes within the district. Table V-1 presents the daily rainfall for the period of study. Hourly rainfall records for this same period are presented in the separate data report. During the 1979 study period, rainfall volume/intensity information was obtained from the University of Michigan recording rain gauge. However, the 1980-1981 rainfall data was measured by an inhouse weighing type rain gauge located at ENCOTEC's office facility.

[illegible]

Precipitation Record
Daily Totals (Inches)

Day	Feb 78	June 78	July 79	Aug 79	Sept 79	Oct 79	[illegible]	[illegible]	[illegible]	Sept 80	Oct 80	Feb 81	April 81	May 81	June 81
1	0	0	.15	.33	0	0	[illegible]	[illegible]	0	.50	.11	.69	0	0	0
2	0	0	0	.07	0	0	[illegible]	0	[illegible]	.23	.30	0	0	0	0
3	.05	0	0	0	0	0		0	[illegible]	0	0	0	0	0	[illegible]
4	0	0	.20	.27	0	0	0	0	0	0	0	0	.06	0	0
5		.09	0	.03	0	0	[illegible]	[illegible]	0	0	0	0	0	0	0
6		0	0	0	0	.40	0	0	0	0	0	0	0	0	0
7		0	0	0	0	0	[illegible]	0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]
9		0	.43	.08	0	0	0	[illegible]	0	.90	0	0	.18	0	0
10		.29	0	.12	0	0	0	0	[illegible]	0	0	1.16	0	[illegible]	0
11		.05	.88	0	0	.22	0	0	[illegible]	0	0	.14	.99	[illegible]	0
12		0	0	0	0	.12	0	0	0	0	0	0	.11	0	0
13		0	0	.18	.10	0	0	0	0	.78	0	0	.14	0	[illegible]
14		0	.28	0	.04	0	[illegible]	0	[illegible]	0	.08	0	.65	[illegible]	[illegible]
15		0	0	0	0	0	[illegible]	0	0	0	0	0	0	[illegible]	0
16		0	0	0	0	0	0		0	0	0	.09	.09	0	0
17		0	0	.59	0	0	0	[illegible]	[illegible]	.67	.11	0	.06	0	0
18		0	0	.31	0	0	0		0	0	0	0	0	0	0
19		.05	0	0	0	0	[illegible]	0	0	0	0	0	.04	0	[illegible]
20		0	0	.34	0	0	0	0	[illegible]	0	0	0	0	0	0
21		0	0	0	0	0	0	0	[illegible]	0	0	0	0	0	[illegible]
22		0	0	0	0	.13	0	[illegible]	0	.57	0	.37	.35	0	[illegible]
23	.13	0	0	.57	0	.04	0	0	0	0	0	.34	.53	0	0
24	0	0	0	0	0	0	0	0	0	0	.45	.03	.07	0	0
25	0	0	.11	0	0	0	0	0	0	.07	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	.15	0	0	0	0	0	0	0	0	0	0	0	[illegible]	0
28	0	.16	0	0	0	0	[illegible]	[illegible]	0	0	0	0	.29	0	0
29	—	.91	0	0	0	0	0	[illegible]	0	0	0	—	.05	.205	0
30	—	1.66	.05	0	0	0	0	0	0	0	0	—	0	[illegible]	0
31	—	—	.20	0	0	0	—	0	[illegible]	—	0	—	—	0	0
Total		3.25	2.30	2.81	0.14	0.91	[illegible]	[illegible]	[illegible]	3.72	1.05	2.82	3.6	[illegible]	[illegible]

— No data available.

C. ATMOSPHERIC SOURCES

Atmospheric contributions during rainfall periods to pollutant loadings were monitored during nine rain events and one snow event between August 1980 and June 1981. Two wetfall collection stations were maintained for three events during 1980. One station was located in the northern section of the study area and the other was located in the southern section. Only one wetfall monitoring station (southern station) was maintained during 1981. The wetfall was collected by using two 11 1/2 inch polyethylene funnels draining into 2-2 liter polyetheylene bottles housed in a portable structure. Table V-2 presents the event wetfall load summaries for the 10 monitored events. In addition, the mean concentration, standard deviation, and variance for selected parameters are found in Table V-3.

TABLE V-3 Wetfall Mean Concentrations (mg/l)

	Mean	St. Dev.	Variance
TSS	4.6	3.9	15.5
TKN	0.89	0.36	0.13
T-P	0.10	0.19	0.03
T-Pb	0.01	0.009	0.00008
T-Fe	0.11	0.08	0.006

TABLE [illegible]

[illegible] Rainfall Load Summary

Parameter	North South Av. Conc. (mg/l)	North South Load (Pound/Acre)	Av. Load (Pound/Acre)	North South Av. Conc. (mg/l)	[illegible]	[illegible]	North South Av. Conc. (mg/l)	North South Av. Load (Pound/Acre)	Av. Load (Pound/Acre)
pH	3.95 5.46	---	---	4.62 5.48	---	---	[illegible] 4.67	---	---
Total Alkalinity	11* 2*	---	---	5* 4*	---	---	[illegible] [illegible]	---	---
Total Suspended Solids	9 6	0.60 0.30	0.45	2 3	[illegible]	[illegible]	13 NA	1.43	1.43
Total Dissolved Solids	18 19	0.70 0.60	0.65	18 2	[illegible]	[illegible]	NA 30	1.0	1.0
Total Kjeldahl Nitrogen	1.3 0.97	0.09 0.005	0.05	0.45 0.69	[illegible]	[illegible]	1.3 0.25+	0.26 0.025+	0.14
Total Phosphorus	0.18 0.06	0.007 0.003	0.005	0.03 0.03	[illegible]	[illegible]	0.85 0.92	0.09 0.09	0.09
Nitrate & Nitrite Nitrogen	NA	NA	NA	0.46 0.48	[illegible]	[illegible]	0.44 0.36	0.07 0.036	0.05
Chemical Oxygen Demand	NA	NA	NA	5 8	[illegible]	[illegible]	NA NA	---	---
Total Iron	0.17 0.07	0.01 0.004	0.007	0.15 0.28	[illegible]	[illegible]	0.1 0.017	0.01 0.002	0.006
Total Lead	0.035 0.019	0.002 0.001	0.015	0.008 0.009	[illegible]	[illegible]	0.018 0.005	0.002 0.0005	0.001
Total Cadmium	NA	NA	NA	<0.0002 [illegible]	[illegible]	[illegible]	0.0008 0.0008	8x10-5 8x10-5	8.5x10-5
Total Zinc	0.058 0.046	0.004 0.003	0.035	0.03 0.01	[illegible]	[illegible]	0.08 0.02	0.009 0.002	0.006
Total Chromium	NA	NA	NA	0.010 0.011	[illegible]	[illegible]	0.007 0.007	0.0008 0.0007	0.0008
Date Start of Event		August 10, 1980			[illegible]			October 24, 1980	
North Rainfall		0.30 inches			[illegible]			0.48 inches	
South Rainfall		0.25 inches			[illegible]			0.45 inches	

* Total acidity in mg/l as $CaCO_3$.

+ Soluble Kjeldahl Nitrogen.

NA - Not available: equipment failure, insufficient [illegible]

TABLE V-2(Continued)

Event Wetfall Load Summary
South Station

Parameter	Concentration mg/l	Load pound/acre	Concentration mg/l	Load pound/acre	Concentration mg/l	Load pound/acre	Concentration mg/l	Load pound/acre
pH	4.05	---	3.83	---	3.84	---	3.73	---
Total Alkalinity	22*	---	9*	---	8*	---	9*	---
Total Suspended Solids	2	0.06	9	2.2	4	0.72	1	0.20
Total Dissolved Solids	12	0.35	18	4.4	16	2.9	10	2.0
Total Kjeldahl Nitrogen	1.3	0.04	0.92	0.23	0.34	0.06	0.63	0.13
Total Phosphorus	0.01	0.0003	0.03	0.007	0.02	0.004	0.01	0.002
Nitrate & Nitrite Nitrogen	0.32	0.009	0.59	0.15	0.42	0.08	0.78	0.16
Chemical Oxygen Demand	8	0.23	10	2.5	<5	<0.90	9	1.8
Total Iron	0.05	0.001	.12	0.03	0.06	0.01	0.06	0.01
Total Lead	0.006	0.0002	0.006	0.001	0.005	0.0009	0.006	0.001
Total Cadmium	<0.0002	<0.0001	---	---	---	---	<0.0002	<0.0001
Total Zinc	0.026	0.0008	---	---	0.01	0.002	0.01	0.002
Total Chromium	0.016	0.0005	---	---	0.006	0.001	0.009	0.002
Date Start Of Event	February 10, 1981 1.3 inches (snow) (= .13 inches rain)		April 11, 1981 1.09 inches		April 13, 1981 0.79 inches		April 22, 1981 0.88 inches	

* Total Acidity in mg/l as $CaCO_3$

TABLE V-2(Continued)

Event Wetfall Load Summary
South Station

Parameter	Concentration mg/l	Load pound/acre	Concentration mg/l	Load pound/acre	Concentration mg/l	Load pound/acre
pH	3.47	---	3.71	---	3.75	---
Total Alkalinity	17*	---	10*	---	9*	---
Total Suspended Solids	<1	<.19	1	0.13	<10	<3.3
Total Dissolved Solids	12	2.3	14	1.9	8	2.7
Total Kjeldahl Nitrogen	0.82	0.15	0.61	0.08	1.4	0.47
Total Phosphorus	0.02	0.004	0.02	0.003	0.01	0.003
Nitrate & Nitrite Nitrogen	1.8	0.34	0.47	0.06	0.46	0.15
Chemical Oxygen Demand	9	1.7	<5	0.67	8	2.7
Total Iron	0.03	0.006	0.17	0.01	0.20	0.07
Total Lead	0.010	0.002	0.005	0.0007	0.002	0.0007
Total Cadmium	---	---	---	---	0.0006	0.0002
Total Zinc	0.02	0.004	0.04	0.005	0.03	0.01
Total Chromium	---	---	---	---	0.006	0.002
Date Start Of Event	May 10, 1981 0.83 inches		May 29, 1981 0.59 inches		June 13, 1981 1.47 inches	

* Total Acidity in mg/l as $CaCO_3$

Using the event mean concentrations listed above the loadings for the average storm in this area (0.3") and the projected annual loads assuming 28 inches total rainfall (Chapter II Synop) on a pounds/acre basis are presented in Table V-4.

Comparing the annual loadings due to atmospheric deposition with those attributed to runoff reveals that atmospheric deposition represents a significant amount of the annual runoff loads for nutrients. Table V-5 presents the minimum and maximum percent of runoff load values for the five key parameters.

TABLE V-5

$\frac{\text{Atmospheric Loading}}{\text{Runoff Loading}}$ %

Parameter	% of Runoff Load
TSS	2-10
TKN	50-100
T-P	50-100
T-Pb	2-100
T-Fe	2-10

As can be seen above, the atmospheric deposition of lead constitutes a major portion of the lead loads (100%) in some areas and below 10% in other areas. This illustrates the fact that in undeveloped/open areas characterized by few roads the major source of

TABLE V-4

Loadings From Atmospheric Contributions
(Pounds/Acre)

System	Av. Rain Event Load Falling On the Area	Projected Load + Entering the Drainage System	Annual Load Falling on the Area	Projected Load Entering the Drainage System
TSS	0.32	0.03-0.06	29	2.9-5.8
TKN	0.06	0.006-0.01	5.7	0.57-1.1
T-P	0.007	0.0007-0.001	0.64	0.06-0.13
T-Pb	0.0007	0.00007-0.0001	0.06	0.006-0.01
T-Fe	0.008	0.0008-0.002	0.70	0.07-0.14

+ Assume minimum runoff coefficient = 0.1
Maximum = 0.2 for the study area.

lead is indeed from atmospheric contributions. However, in urban areas this atmospheric contribution is small (<10%) when compared to lead contributions from roads and parking lots. Atmospheric contributions of total suspended solids and iron to the runoff loads appear to be minor throughout the entire study area.

D. RUNOFF SOURCES

The major contributor of pollutant loads to the Argo-Geddes reach of the Huron River is attributed to stormwater runoff. In attempting to examine the sources of these pollutant loads it is necessary to look at the relative land uses that are associated with the varying pollutant loads. Land use versus pollutant loading will be examined in two different ways. First, land use versus event mean concentration will be considered and then land use versus pounds per acre will be discussed.

An average event mean concentration has been determined based on all monitored events at each station to provide a basis for comparison between the various drainage districts. The average event mean concentration has also been used in conjunction with rainfall volumes and runoff coefficients for the various districts to determine average event loadings and annual loadings for each district or subdistrict. Inherent in utilizing average event mean concentration for these calculations is the assumption that event mean concentration is independent of runoff volume.

This assumption can be tested by determining the correlation coefficient between event mean concentrations (EMC) and runoff for selected parameters at the various monitoring stations. Correlation coefficients ranged from -.40 to +.70 for most parameters at most of the stations. These findings tend to support the assumption. However higher correlation coefficients (+.90 - +.98) were determined at the South Arm Inlet, the Outlet from the Pittsfield - Ann Arbor Retention Basin, and at the Outlet from the Swift Run Wetlands. These results indicate that event mean concentrations are dependent on flow at these three stations.

This would be expected as discussed in Chapter IV on BMP efficiencies in that these stations represent controlled sources. Higher flows at these stations reduces the settling times, increases velocity and also contributes to scouring which all effect the concentration levels leaving the basins.

All of the drainage areas have been subdivided into "sub-drainage areas", where applicable, to provide as much resolution as possible for examining land use contributions of pollutants. Table V-6 presents these "sub-areas" along with the number of acres in the sub areas, percent residential, percent commercial/industrial and percent imperviousness. All of this material is found in greater detail in Chapter II.

The various drainage districts or sub-drainage districts are ranked by their measured event mean concentrations from highest concentration to lowest concentration in Table V-7. Five key parameters were examined (TSS, TKN, TP, TPb, TFe) and assigned a

TABLE V-6

Ranking By Event Mean Concentration
(High-Low)

	Drainage Area	# Of Acres	% Residential	% Comm/Ind.	% Imperviou
1.	Pittfield - Ann Arbor Drain Below Retention Basin to River	1,491	59	7	19
2.	Traver Creek Drain Below Retention Basin to River	2,075	23	5	12
3.	Pittsfield - Ann Arbor Drain Outlet Entire Drain	6,363	43	17	22
4.	Allen Drain Outlet Entire Drain	3,800	58	11	34
5.	Swift Run Drain Below Wetlands to River	1,848	49	6	21
6.	Pittsfield - Ann Arbor Retention Basin North Arm Inlet	2,871	54	13	26
7.	Swift Run Drain Outlet Entire Drain	3,075	34	4	14
8.	Swift Run Wetlands Inlet	1,207	11	1	3
9.	Traver Creek Drain Outlet Entire Drain	4,402	12	3	9
10.	North Campus Drain Outlet Entire Drain	1,541	46	16	19
11.	Pittsfield - Ann Arbor Retention Basin South Arm Inlet	2,001	14	30	21
12.	Traver Creek Retention Basin Inlet	2,303	2	2	6

TABLE V-7

Ranking By Event Mean Concentration
(High-Low)

		EMC (mg/l)			
	Drainage Area	TSS	TKN	T-P	T-Pb
1.	Pittsfield - Ann Arbor Drain Below Retention Basin to River	418	1.6	0.06	0.04
2.	Traver Creek Drain Below Retention Basin to River	135	1.3	0.10	0.03
3.	Pittsfield - Ann Arbor Drain Outlet Entire Drain	213	1.2	0.09	0.03
4.	Allen Drain Outlet Entire Drain	109	0.90	0.29	0.04
5.	Swift Run Drain Below Wetlands to River	266	0.90	0.10	0.03
6.	Pittsfield - Ann Arbor Retention Basin North Arm Inlet	59	1.1	0.25	0.04
7.	Swift Run Drain Outlet Entire Drain	135	0.90	0.09	0.01
8.	Swift Run Wetlands Inlet	72	1.1	0.13	0.01
9.	Traver Creek Drain Outlet Entire Drain	80	0.96	0.08	<0.03
10.	North Campus Drain Outlet Entire Drain	63	0.88	0.11	0.01
11.	Pittsfield - Ann Arbor Retention Basin South Arm Inlet	41	0.80	0.10	0.02
12.	Traver Creek Retention Basin Inlet	31	0.89	0.09	0.001

numerical value between one and twelve for each of the drainage areas. These numerical rankings were then added for each of the twelve drainage areas giving a means of ranking these different areas on the basis of the five key parameters. As would be expected the areas generating the highest concentrations of pollutants are the highly urbanized uncontrolled drainage areas. Pittsfield - Ann Arbor Drain below the retention basin is the drainage area that ranks highest as generating the overall highest pollutant concentrations among the drainage area. This drainage area is characterized by large residential areas and numerous commmericial strip developments. The next areas (in order) are Traver Creek Drain below the retention basin, Allen Drain, Swift Run Drain below the wetlands and Pittsfield - Ann Arbor Retention Basin - North Arm Inlet all of which are composed of urbanized land uses (20-35 percent imperviousness). In contrast to these highly urbanized areas are the areas that consist mostly of undeveloped or open land. Traver Creek Retention Basin Inlet illustrates this type of area. The event mean concentrations of the five key parameters are all low when compared to those measured at Pittsfield - Ann Arbor below the retention basin, Allen Drain, etc. Total suspended solids and total lead event mean concentrations for Pittsfield - Ann Arbor Drain below the retention basin, Allen Drain and Traver Creek Inlet are as follows respectively; TSS (mg/l) 418, 109, 31; T-Pb (mg/l) 0.04, 0.04, 0.001. The low lead values found in the upper Traver Creek Retention Basin reflects the fact that there are few roads present in this area.

The Swift Run Wetlands Inlet drainage area is also composed of very small amounts of residential and commmercial land uses and would be expected to produce similar concentrations to those found in the Traver Creek Retention Basin Inlet drainage area. However the City of Ann Arbor landfill is located in this drainage area immediately upstream of the sampling site. The contributions from this landfill appear to raise the event mean concentrations to levels above those found in Traver Creek and in some cases up to levels similar to those found from more highly urbanized land uses.

In between the highly urbanized areas and the open/undeveloped areas falls the urbanized areas with controls represented by the South Arm Inlet to the Pittsfield - Ann Arbor Retention Basin. This area is comprised of large commercial areas with some residential areas. Because of the large parking lots associated with the commercial areas the percent imperviousness of this drainage areas is twenty-one percent. This type of land use composition would be expected to produce concentrations similar to those found in other highly urbanized areas. However the runoff in this area is controlled by three retention basins before entering the retention basin BMP. These controls appear to lower the event mean concentrations to levels similar to those found from undeveloped/open land uses. As mentioned earlier, the retention basins removal efficiencies are lower for larger more intense rains and the event mean concentrations for these events would be closer to those found from other highly developed land use areas during very large events.

Another example of a controlled drainage area from an urbanized area is the North Campus Drain. A large percentage of this drainage area is comprised of residential land uses (i.e. apartment complexes). However these apartment complexes contain retention basins on site to control stormwater runoff. These controls again lower the event mean concentrations to levels that are lower than would be expected for this type of land use composition. In general the highly urbanized land use areas generate higher event mean concentrations than does the controlled urbanized areas and the open/undeveloped areas.

The second and perhaps most meaningful way to compare land use versus pollutant loadings is to evaluate the actual number of pounds of pollutants the different types of land uses deliver to the various drainage systems. This method accounts for the runoff volumes which are generated from the different land uses in addition to the concentration of the materials. Examining the event mean concentration provides a comparison of the quality ("relative dirtiness") of the runoff waters from the varous land mix types. However high concentrations are not necessarily critical in terms of effects on the river if the runoff volumes associated with these high concentrations are small. This combination may produce low runoff loadings (pound of material) to the drain and eventually to the Huron River. Obviously this can work in reverse with low pollutant concentrations and high flows also producing low runoff loadings. In contrast, comparing the varous drainage areas based on pounds/acre accounts for both the concentration of the pollutants and the runoff volume generated from each area.

The runoff volume is dependent on the rainfall amount and the runoff coefficient for the drainage area. The runoff coefficients are dependent on factors like land use categories, percent imperviousness and rainfall intensity. Therefore highly urbanized areas generally have higher runoff coefficients than do undeveloped/less urbanized areas. Table V-8 presents the pollutant loads that would be expected from the average rain event (0.3 inch based on SYNOP rainfall analysis, Chapter II) for the various drainage/sub-drainage areas. Measured event mean concentrations and runoff coefficients were used to make these projections. Table V-9 presents the annual loads (based on 28 inches of rainfall) that would be expected for these drainage areas. Table V-10 presents the annual pollutant loads on a pound/acre per year basis which will be the format used for comparison purposes. It should be noted that some drainage districts loads values are influenced by upstream retention basins.

Ranking the five total drainage districts in order from high to low loadings places the Pittsfield - Ann Arbor Drain District and the Allen Drain District in the first two spots. These drainage districts are comprised of highly urbanized areas with high runoff coefficients and generally high event mean concentrations when compared to the other districts. The Swift Run Drain is third reflecting the urbanized downstream section below the wetlands. The Traver Creek Drain is above the North Campus Drain in most parameters as a result of the contributions of the downstream urban section below the retention basin. The North Campus Drain is ranked last reflecting the fact that it is from a controlled (retention basin) urbanized source.

TABLE V-8

POLLUTANT LOADS - MEAN RAINFALL EVENT
(0.3 Inches Precipitation)
(pounds/event)

	Total Suspended Solids	Kjeldahl Nitrogen	Total Phosphorus	Total Lead	Total Iron
Pittsfield - Ann Arbor Drain	18,500	105	7.8	2.6	430
Allen - Drain - Total District	6,600	94	22	10	180
Swift Run - Total District	4,200	28	2.8	0.4	110
Traver Creek - Total District	2,600	32	2.5	1.0	53
North Campus - Total District	660	9	1.2	0.1	19
Swift Run Above Wetland	1,200	18	2.1	0.2	20
Swift Run Below Wetland	4,000	13	1.6	0.4	100
Pittsfield - Ann Arbor Drain North Inlet	1,200	22	4.9	0.8	37
Pittsfield - Ann Arbor Drain South Inlet	1,000	20	2.5	0.5	29
Pittsfield - Ann Arbor Drain - Below Retention	16,900	65	2.4	1.6	380
Traver Creek - Above Retention	500	15	1.6	.02	13
Traver Creek - Below Retention	2,100	20	1.5	1.0	40

TABLE V-9

ANNUAL POLLUTANT LOADS

(Pounds/Year)
(Based on 28 inches of rainfall)

	Total Suspended Solids	Kjeldahl Nitrogen	Total Phosphorus	Total Lead
Pittsfield - Ann Arbor Drain	1,730,000	9,800	730	240
Allen - Drain - Total District	610,000	8,700	2,000	930
Swift Run - Total District	395,000	2,600	260	37
Traver Creek - Total District	246,000	3,000	230	93
North Campus - Total District	61,000	860	110	10
Swift Run - Above Wetland	112,000	1,700	200	15
Swift Run - Below Wetland	375,000	1,200	150	37
Pittsfield - Ann Arbor Drain North Inlet	112,000	2,100	460	75
Pittsfield - Ann Arbor Drain South Inlet	93,000	1,900	230	47
Pittsfield - Ann Arbor Drain Below Retention	1,570,000	6,100	225	150
Traver Creek - Above Retention	49,500	1,400	150	1.6
Traver Creek - Below Retention	196,000	1,900	140	93

TABLE V-10

ANNUAL POLLUTANT LOADS
(Pounds/Acre Per Year)
(Based on 28 inches of rainfall.)

	Total Suspended Solids	Kjeldahl Nitrogen	Total Phosphorus	Total Lead	Total Iron
Pittsfield - Ann Arbor Drain*	270	1.5	.11	.04	6.3
Allen - Drain - Total District	160	2.3	.52	.24	4.5
Swift Run - Total District*	128	0.8	.08	.012	3.3
Traver Creek - Total District	56	0.7	.05	.02	1.1
North Campus - Total District*	40	0.56	.07	.006	1.2
Swift Run - Above Wetland	93	1.4	.17	.012	1.5
Swift Run - Below Wetland	200	0.7	.08	.02	5.2
Pittsfield - Ann Arbor Drain - North Inlet	39	.71	.16	.026	1.2
Pittsfield - Ann Arbor Drain -* South Inlet	46	.93	.11	.023	1.4
Pittsfield - Ann Arbor Drain - Below Retention	1,050	4.1	.15	.10	24
Traver Creek - Above Retention	22	0.6	.06	.0006	.52
Traver Creek - Below Retention	94	0.9	.07	.045	1.8

* Have upstream retention basins which may remove some load.

Dividing the drainage districts into sub-districts provides additional information on various land use runoff contributions. The drainage area below the Pittsfield - Ann Arbor Retention Basin characterized by large residential areas and numerous commercial strip developments is by far the largest contributor of total suspended solids, kjeldahl nitrogen, total lead and iron. As mentioned earlier this is the district that also had the highest event mean concentrations for most of the five key parameters. Being high in pounds/acre plus event mean concentration indicates that the runoff volume is substantial in this area as would be expected from an urbanized area. The drainage area above the retention basin is also urbanized with large commercial land uses on the south inlet and high residential land uses on the North inlet. The North Inlet ranked higher on an event mean concentration basis than the South Inlet, but the reverse is true when the two inlets are compared on a pounds/acre basis. Thus, even though the North Inlet is comprised of more drainage area, and has a higher concentration, the South Inlet produces more runoff per inch of rain than does the North Inlet resulting in more loadings even though controls do exist on this inlet. Runoff coefficients measured during the monitored rain events for both inlets clearly show the higher runoff volume in the South Arm branch (Chapter IV). It should be noted that the North Arm Inlet's loads are lower than would be expected when comparing these loads to loads generated from similar types of land uses. The reason for the lower loading rates is found to be in the lower than anticipated runoff volumes. Lower runoff coefficients in comparison to runoff coefficients found in similar land uses were measured for this drainage area (Chapter IV).

The Traver Creek Inlet (open/undeveloped land) is characterized by low event mean concentrations, low runoff coefficients and as would be expected low loading rates. Its counterpart as far as land use classification is concerned is the Swift Run Inlet. However the contributions from the landfill increases the event mean concentrations as mentioned earlier and also influences the runoff coefficient. More runoff is generated per inch of rain at the Swift Run Inlet than at Traver Creek Inlet. These factors push the loading rates of the Swift Run Inlet to levels comparable to loadings seen from highly urbanized areas.

Generally speaking, the same patterns seen with the land use versus event mean concentrations are seen when looking at loadings on a pound/acre basis. Highly urbanized areas as illustrated by Allen Drain, Pittsfield - Ann Arbor Drain below the retention basin, Traver Creek Drain below the retention basin and Swift Run Drain below the wetlands and characterized by higher event mean concentrations and high runoff coefficients produce the greatest loads to the Huron River. Undeveloped/open land uses generate smaller loads in comparison due mainly to the fact that there is not as much runoff being generated off of this type of land use. Loads from urbanized landuses with controls generally fall in between the high loads from urbanized areas and the low loads from undeveloped land due mainly to the lowering of the pollutant's event mean concentration by the control device.

CHAPTER VI. HURON RIVER ASSESSMENT

INTRODUCTION

The water quality of the Huron River between Argo Dam and Geddes Dam and the impacts of stormwater runoff on its integrity along this reach are presented in this section. The character and condition of the Huron River are described through river hydrology, beneficial uses, waste source inputs, and historical river data. The impact of stormwater runoff to the river is presented through the integration of the data generated from the river and drain studies done in this NURP project and the available historical data.

BENEFICIAL USES

The Huron River is widely used for recreational activities and as a source of public water supplies. The reach of river being investigated in this study (between Argo Dam and Geddes Dam) is extensively used for recreational activities. The impoundment (Geddes Pond) serves as a focal point in the City parks and recreation program. Development of park facilities along the pond has been quite extensive in the past few years. Picnic grounds, bike and jogging paths, islands with connecting bridges, a canoe livery, and a boat launching ramp have all been part of a multi-million dollar improvement program. Thus, the water quality in this section of the river is quite important to the citizens in the area. A strong commitment to keep the river and park system clean exists among the local residents and local governments. In addition, the Huron River Watershed Council and the Ecology Center of Ann Arbor serve as "watchdogs" for the well being of the river.

The river in this section was (until recently) designated for "partial body contact, warm water fish". This designated use is applied by the State of Michigan's Water Resources Commission, (WRC) and applies to the river and its tributaries. However, recently this section of the river (Geddes Pond) has been designated for "total body contact, warm water fish". The designated use "is the goal toward which water quality planning and improvemnt measures are directed".

The City of Ypsilanti has its auxillary water intakes in Geddes Pond. The city has an agreement with the City of Ann Arbor to withdraw up to 7.5 cfs (4.87 MGD) from these auxillary intakes. However, in view of the existing contractual agreements between the City of Ypsilanti, Ypsilanti Township and the City of Detroit it appears the Ypsilanti Community will be obtaining all of their drinking water from the City of Detroit by the year 1995. It is assumed then that the 7.5 cfs raw water intake at Geddes Pond will be maintained as an emergency connection.(1)

Although the City of Ann Arbor's water intakes are located just above the study area (Barton Pond) they do have the potential to increase or decrease the flow in the downstream section through water diversion and impoundment level regulation. The City of Ann Arbor uses for its source of drinking water surface water from the Huron River as well as ground water. The city has the capacity to pump approximately 61.6 cfs (40 MGD) from Barton Pond. Together with its wells the City of Ann Arbor will have the capacity to meet an instantaneous water demand (disregarding in system storage) of approximatley 76.6 cfs (49.75 MGD) by the year 1995. The maximum month water demand for the City of Ann Arbor for the year 1995 has been estimated to be 53.7

cfs (34.87 MGD). As shown above, the city has the capacity to meet this water demand solely by use of its surface water source. However, in regards to the concerns over low flows in the Huron River during drought conditions it is highly unlikely that the city would utilize only one source (surface water) to meet this demand. The City of Ann Arbor has control over the main surface water impoundments in the area (Barton, Argo, and Geddes Ponds) and has agreed to guarantee a minimum flow of 50 cfs (32.47 MGD) over Geddes Dam at all times.(1)

WATER QUALITY STANDARDS - STATE OF MICHIGAN

The purpose of the Michigan water quality standards as stated in the regulations is as follows:

> Rule 1041. It is the purpose of the water quality standards as prescribed by these rules to establish water quality requirements applicable to the Great Lakes, their connecting waterways and all other surface waters of the state, which shall protect the public health and welfare, enhance and maintain the quality of water, serve the purposes of the United States Public Law 92-500 and the commission act; and which shall protect the quality of waters for recreational purposes, public and industrial water supplies, agriculture uses, navigation and propagation of fish, other aquatic life and wildlife.

Standards for selected parameters of interest are presented below. The complete water quality standards document is presented in Appendix II.

A. Suspended Solids

There is no numerical standard. Rule 1050 states "all waters of the state shall contain no unnatural turbidity, color, and films, floating solids, foams, settleable solids, or deposits in quantities which are or may become injurious to any designated use".

B. Dissolved Solids

Rule 1051. (1) The addition of any dissolved solids shall not exceed concentrations which are or may become injurious to any designated use. Point sources containing dissolved solids shall be considered by the commission on a case-by-case basis and increases of dissolved solids in the waters of the state shall be limited through the application of best practicable control technology currently available as prescribed by the administrator of the United States Environmental Protection Agency pursuant to Section 304 (b) of United States Public Law 92-500, except that in no instance shall total dissolved solids in the waters of the state exceed a concentration of 500 milligrams per liter as a monthly average nor more than 750 milligrams per liter at any time, as a result of controllable point sources.

C. Hydrogen ion concentration

Rule 1053. The hydrogen ion concentration expressed as pH shall be maintained within the range of 6.5 to 8.8 in all waters of the state except so otherwise prescribed by rule 1080. Any artificially induced variation in the natural pH shall remain within this range and shall not exceed 0.5 units of pH.

D. Toxic substances

Cadmium	10.0 ug/l
Lead	50.0 ug/l

E. Plant nutrients

Rule 1060. Nutrients originating from domestic, industrial, municipal or domestic animal sources shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached and floating plants, fungi or bacteria which are or may become injurious to the designated uses of the waters of the state. Phosphorus which is or may readily become available as a plant nutrient shall be controlled from point source discharges by the application of methods utilizing best practicable waste treatment technology for control of total phosphorus, with the goal of achieving a monthly average effluent concentration of one milligram per liter as P.

F. Fecal Coliform

Rule 1062. (1) Waters of the state protected for total body contact recreation shall contain not more than 200 fecal coliforms per 100 milliliters and all other waters of the state shall contain not more than 1,000 fecal coliforms per 100 milliliters. These concentrations may be exceeded if due to uncontrollable non-point sources.

(2) Compliance with the fecal coliform standards prescribed by subrule (1) shall be determined on the basis of the geometric average of any series of 5 or more consecutive samples taken over not more than a 30-day period.

G. Dissolved oxygen; Great Lakes, connecting waterways and inland streams

Rule 1064. A minimum of 6 milligrams per liter of dissolved oxygen in all Great Lakes and connecting waterways shall be maintained and, except for inland lakes as prescribed in rule 1065, a minimum of 6 milligrams per liter of dissolved oxygen shall be maintained at all times in all inland streams designated by these rules to be protected for coldwater fish. In all other waters, except for inland lakes as prescribed by rule 1065, a minimum of 5 milligrams per liter of dissolved oxygen shall be maintained as a daily average and no single value shall be less than 4 milligrams per liter in waters naturally capable of supporting warmwater fish.

As can be seen with the above water standards, a problem exists in that there are no numerical standards for some very important parameters (i.e. total suspended solids, phosphorus, nitrogen). The problem is further compounded with exceptions to the numerical standards for "uncontrollable" non-point sources as the case for fecal coliform. Basically there is no comprehensive list of numerical standards to compare with storm water quality data. However, in addition to the established state standards, a set of guidelines or targeted goals have been defined by several governmental agencies for various chemical constituents. These guidelines have been compiled and are attached to the State Water Quality Standards in the Appendix. Key parameters included in these guidelines are:

Suspended Solids	25 mg/l
Total Phosphorus	> 0.5 mg/l
Nitrogen-Ammonia	.4 mg/l
Total Organic Nitrogen	> .8 mg/l

HYDROLOGICAL CONDITIONS

The drainage area of the Huron River at the USGS gaging station (#04174500) in Ann Arbor is 729 square miles. The total drainage area of the Huron River at its outlet into Lake Erie is approximately 908 square miles. During the late nineteenth century due to development in water power, the character of the river between Dexter and the mouth changed from a free-flowing stream to a series of impoundments. Between Mast Road at Dexter and the mouth, 29.4 miles or 70 percent of the rivers distance is now impounded water. The section of Huron River between Argo Dam and Geddes Dam (Figure VI-1) that this study is concerned with is approximately 4.5 miles in length with over one-half the distance being made up of the impoundment created by Geddes Dam. The remainder of the reach is a free-flowing stream.

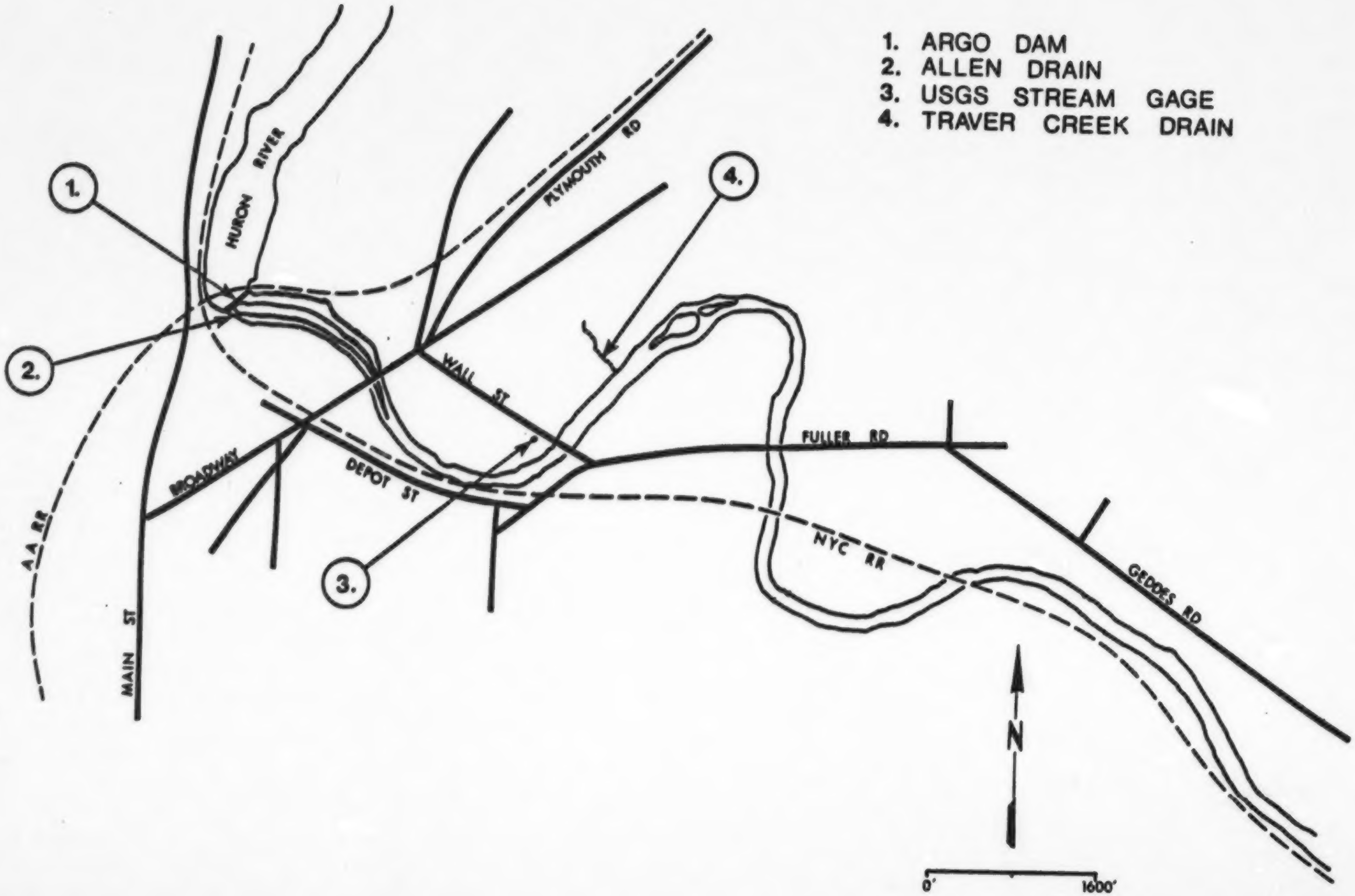

1. ARGO DAM
2. ALLEN DRAIN
3. USGS STREAM GAGE
4. TRAVER CREEK DRAIN
1.
2.
3.
4.
HURON RIVER
PLYMOUTH RD
WALL ST
FULLER RD
BROADWAY
DEPOT ST
NYC RR
GEDDES RD
A A RR
MAIN ST
N
0'
1600'

Figure VI-1 Upper Geddes Pond

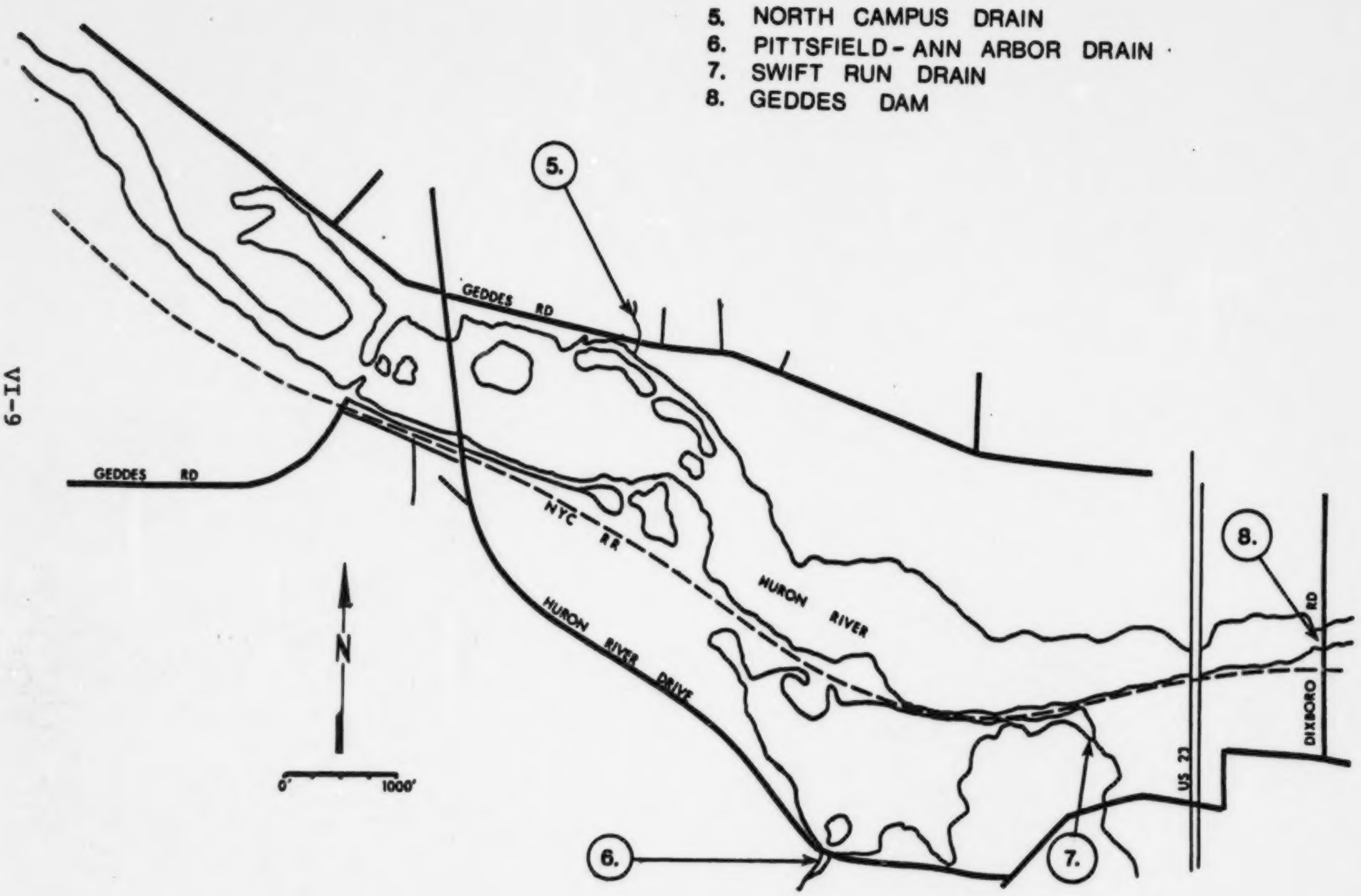

5. NORTH CAMPUS DRAIN
6. PITTSFIELD - ANN ARBOR DRAIN
7. SWIFT RUN DRAIN
8. GEDDES DAM
5.
GEDDES RD
GEDDES RD
NYC RR
HURON RIVER
HURON RIVER DRIVE
N
0' 1000'
US 23
DIXBORO RD
8.
6.
7.

Figure VI-1 (Continued) Lower Geddes Pond

Surface water records on the Huron River at Ann Arbor date back to February 1904. The gaging was done at Geddes Dam until December 1914, when the gaging station was moved to Barton Dam, where it continued through September 1947. During this period water leaking through the turbine gates required a correction to be made to the gaged river flows. Even though corrections were made it should be noted that the USGS stated that it is quite probable that many of the low-flow records during the years just prior to 1940 are considerably in error and that they should be used with caution. This is especially of concern for studies involving low flows, where this component of flow becomes very significant, and any error in its estimation makes the drought flow estimates considerably in error(1).

The gaging station was moved in September 1947 to its present location which is 100 feet upstream of the Wall Street bridge in Ann Arbor. The flow data collected at this location is considered good. This data has been reported in past studies in two different ways. One set of figures adjusts the flows for the water that is being diverted upstream by the City of Ann Arbor for its drinking water supply. These adjusted figures are good when dealing with low flow projections. Table VI-1 presents the lowest mean 7-day recorded and adjusted flows on the Huron River for Climatic Years 1949 to 1972. Table VI-2 presents the adjusted mean flow for a number of consecutive days.

Unadjusted flow rates are being used in this report for projection purposes. It is felt that the city's water diversion does not have a significant impact on the river's integrity and that unadjusted numbers reflect the true status of the river for projection purpose. Similar views are expressed by the USGS and are reflected by the fact that

TABLE VI-1

Lowest Mean 7-Day Recorded and Adjusted Flows on the Huron River for Climatic Years 1949 to 1972 in Cubic Feet Per Second.

Climatic Year	1 USGS Lowest Mean 7-day Flow	2 Ann Arbor Water Supply Diversion	3 Lowest Mean 7-day Adjusted Flow (1+2)
1949	117	3	120
1950	144	5	149
1951	184	6	190
1952	149	5	154
1953	82	3	85
1954	93	6	99
1955	89	10	99
1956	162	10	172
1957	162	9	171
1958	98	9	107
1959	61	10	71
1960	112	12	124
1961	119	14	133
1962	86	12	98
1963	66	12	78
1964	57	14	71
1965	44	11	55
1966	70	16	86
1967	93	21	114
1968	305	17	322
1969	147	22	169
1970	98	23	121
1971	35	32	67
1972	130	26	156

Reference: Environmental Assessment for Wastewater Management in the Ann Arbor - Ypsilanti Areas of the Huron Valley, Washtenaw County, Michigan. Environmental Control Technology Corporation, Ann Arbor, Michigan 1976.

TABLE VI-2

Adjusted Lowest Mean Flow for the Following Number of Consecutive Days in cfs.

Adjusted Lowest Mean Flow in CFS

Climatic Year	7 day	14 day	30 day	60 day	90 day
1949	120	134	142	161	185
1950	149	161	179	211	275
1951	190	201	218	220	269
1952	154	167	169	181	182
1953	85	114	123	128	138
1954	99	114	124	129	164
1955	99	104	113	130	150
1956	172	175	180	194	229
1957	171	181	205	220	240
1958	107	110	128	137	143
1959	71	83	110	129	155
1960	124	128	143	157	173
1961	133	139	150	165	223
1962	98	113	127	139	161
1963	78	80	85	90	93
1964	71	75	89	109	110
1965	55	58	76	86	104
1966	86	93	104	116	116
1967	114	122	134	152	169
1968	322	339	345	366	393
1969	169	173	189	224	261
1970	121	132	146	196	249
1971	67	69	74	89	103
1972	156	181	197	219	226

Reference: Environmental Assessment for Wastewater Management in the Ann Arbor - Ypsilanti Areas of the Huron Valley, Washtenaw County, Michigan. Environmental Control Technology Corporation, Ann Arbor, Michigan. 1976.

all daily flows are reported without being adjusted and that all statistical analyses on the flow data is done on unadjusted flow values. Table VI-3 presents monthly mean discharge adjusted and unadjusted values for water years 1977-1980. (See Appendix III for complete table) As can be seen from this table, the difference between adjusted and unadjusted annual mean values range between 3 and 6 percent for these four years. Greater differences between adjusted and unadjusted monthly values are experienced for months during low flow periods as would be expected.

Daily unadjusted flow rates for the river as measured at the Wall Street USGS gage for the entire period of study are presented in Tables VI-4-6. In addition, Table VI-7 presents statistical summaries of the highest and lowest mean discharge for various consecutive days (1,3,7,14 etc.) for the period of record (1915-1973). Additional statistical information on the Huron River can be found in Appendix III.

As mentioned earlier, the area of concern of this report consists of a stretch of river that is comprised of an impoundment over one-half its length. This impoundment (Geddes Pond) like other impoundments along the river, greatly influence the water quality dynamics of the Huron River. Factors like increased time of passage, increased residence time and decreases in velocity of flow create conditions that are not as prevalent in the free flow sections. These factors can contribute to among other things, deposition of solids and heavy metals and increased nutrient uptake leading to algal blooms. As reported in SEMCOG's "Water Quality in Southeast Michigan: The Huron River Basin"(2), studies have been done to try to measure time-of-passage through the various impoundments using

TABLE VI-3

Discharge, In Cubic Feet Per Second
Mean Values

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Total
Water Yr. 1980													
Total	5,104	11,617	15,637	14,162	8,368	21,786	35,364	19,618	18,443	6,710	13,576	16,874	187,259
Mean	165	387	504	457	289	703	1,179	633	615	216	438	562	512
Max.	248	654	975	689	558	1,304	1,710	968	961	333	755	843	1,710
Min.	86	182	288	308	216	248	623	304	171	98	208	385	86
Ad. Mean+	184	405	521	473	306	720	1,196	652	635	242	458	582	531
Water Yr. 1979													
Total	5,259	8,691	9,752	9,102	5,788	23,560	27,438	16,535	7,167	11,451	7,899	3,507	136,149
Mean	170	290	315	294	207	760	915	533	239	369	255	117	373
Max.	357	622	381	412	232	1,270	1,430	1,000	550	682	533	313	1,430
Min.	97	187	197	235	140	250	661	295	86	157	108	55	55
Ad. Mean+	189	309	332	312	227	779	935	556	267	395	277	143	395
Water Yr. 1978													
Total	6,792	10,331	15,508	10,230	8,853	26,708	28,990	18,442	8,192	4,627	3,049	3,110	144,832
Mean	219	344	500	330	316	862	966	595	273	149	98	104	397
Max.	430	471	764	438	372	2,300	1,630	1,140	500	330	140	224	2,300
Min.	110	190	287	269	256	197	456	233	190	81	43	40	40
Ad. Mean+	239	363	516	346	334	879	984	616	297	177	129	131	418
Water Yr. 1977													
Total	7,450	9,948	7,542	5,952	7,709	23,850	25,087	11,901	6,923	6,003	3,684	5,128	121,177
Mean	240	332	243	192	275	769	836	384	231	194	119	171	332
Max.	485	611	309	220	599	1,390	1,280	1,010	391	611	171	354	1,390
Min	150	136	190	165	194	387	276	153	139	106	93	64	64
Ad. Mean+	262	353	263	212	294	789	858	408	255	218	139	192	353

+ Adjusted for diversion for municipal supply; record furnished by City of Ann Arbor.

TABLE VI-4 HURON RIVER

Average Daily Flow Rates (cfs)
Wall Street Gauge (USGS 04174500)
Ann Arbor, Michigan

January - December 1979

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	412	243	250	763	560	436	682	233	55	113	211	551
2	392	255	266	755	740	357	384	303	157	95	188	457
3	267	247	351	757	900	335	452	327	160	131	274	443
4	365	255	947	685	1000	336	481	533	313	79	334	470
5	354	253	1270	661	850	280	478	476	106	135	204	563
6	353	252	1090	874	760	200	511	386	112	123	413	532
7	335	220	1160	936	740	256	484	349	86	144	377	386
8	352	211	1140	821	710	301	423	233	124	163	246	378
9	350	307	1030	919	680	319	489	266	151	134	364	371
10	332	257	1010	1010	570	347	407	293	116	153	389	388
11	314	235	983	967	600	230	413	306	131	168	353	386
12	281	233	900	1050	680	228	611	181	103	174	524	399
13	277	263	856	1120	650	247	448	195	87	164	496	384
14	279	230	853	1430	480	216	335	288	134	174	171	369
15	310	215	804	1410	370	230	396	198	160	178	275	354
16	271	235	750	1240	400	194	342	162	128	138	273	366
17	287	275	721	1140	430	406	344	189	126	133	291	322
18	286	277	731	1110	480	226	364	362	87	150	269	319
19	285	214	720	1060	430	145	303	150	89	117	279	294
20	263	220	714	1090	390	90	272	244	124	167	284	274
21	260	195	700	1020	350	128	221	277	90	200	276	276
22	260	203	559	800	295	106	228	259	107	183	365	308
23	245	224	599	720	326	158	303	235	91	227	469	348
24	243	215	630	770	384	162	249	270	95	236	486	580
25	250	225	706	850	463	109	345	283	69	183	463	829
26	246	205	600	700	421	125	374	156	99	156	554	955
27	250	225	564	680	398	86	199	138	103	154	634	883
28	252	232	568	580	402	125	157	166	105	153	616	823
29	255	---	610	720	329	239	344	171	90	162	566	751
30	241	---	707	700	388	550	204	162	109	146	544	709
31	239	---	789	---	359	---	208	108	---	177	---	679

TABLE VI-5 HURON RIVER

Average Daily Flow Rates (cfs)

Wall Street Gauge (USGS 04174500)

Ann Arbor, Michigan

January - December 1980

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	669	267	300	1060	947	547	228	195	642	510	392	376
2	637	264	268	1010	893	481	272	447	826	571	458	472
3	578	263	275	1080	810	833	246	632	689	453	602	517
4	582	256	262	1530	778	940	189	549	519	470	484	489
5	531	229	265	1680	576	702	248	382	522	478	410	466
6	456	235	252	1550	662	651	222	356	486	439	420	467
7	446	233	237	1380	656	779	248	371	475	361	423	569
8	404	218	250	1310	614	895	217	395	381	406	426	745
9	376	229	247	1380	525	810	229	426	452	414	423	881
10	369	221	281	1430	517	713	203	406	428	411	419	855
11	528	231	252	1370	482	665	202	357	405	394	409	770
12	446	216	244	1220	555	626	140	248	369	390	417	735
13	449	213	251	1270	581	586	195	277	394	364	428	711
14	459	228	266	1300	556	567	177	384	476	270	446	672
15	461	204	260	1430	510	868	172	361	442	356	576	648
16	453	216	360	1350	407	913	319	308	394	317	626	637
17	444	226	1320	988	494	644	262	237	588	351	440	571
18	504	224	1260	1290	894	603	181	353	693	368	327	539
19	488	223	1090	1210	907	646	222	291	636	421	351	492
20	460	212	1260	1100	793	656	175	597	569	393	371	443
21	447	229	1260	1070	709	535	179	735	547	244	384	435
22	432	439	1240	987	693	450	199	720	607	358	382	413
23	417	542	1160	958	660	426	180	601	667	396	356	414
24	355	441	1140	873	626	446	163	475	648	419	372	395
25	375	397	1180	857	586	392	91	401	676	426	356	411
26	326	332	1130	880	524	404	129	446	596	400	352	416
27	352	366	1010	838	411	385	154	368	583	437	351	377
28	340	337	957	897	291	343	176	371	568	401	382	383
29	317	305	956	607	359	163	302	371	540	385	391	394
30	301	---	978	743	483	267	206	488	558	389	383	387
31	295	---	1020	---	574	---	229	570	---	394	---	387

TABLE VI-6 HURON RIVER

Average Daily Flow Rates (cfs)
Wall Street Gauge (USGS 04174500)
Ann Arbor, Michigan

January - October, 1981

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	382	316	1440	814	675	575	267	229	223	1650		
2	400	310	1330	621	734	449	239	240	190	1320		
3	365	312	1200	374	725	457	264	270	420	1230		
4	370	306	1080	415	547	470	147	250	1110	1180		
5	375	292	938	502	562	445	191	238	1210	1450		
6	357	278	919	533	633	345	263	193	866	1200		
7	367	316	876	582	558	331	192	176	860	1490		
8	381	322	821	510	513	331	197	185	1020	1090		
9	357	309	777	518	509	439	228	146	692	1110		
10	347	309	743	490	614	325	180	126	585	1030		
11	345	358	643	543	935	317	154	159	578	929		
12	363	358	644	732	981	294	150	142	670	898		
13	323	384	638	1010	864	419	152	136	449	733		
14	334	363	621	1140	970	646	128	131	517	864		
15	301	341	601	1210	1170	730	182	148	470	821		
16	311	398	567	972	1060	637	---	149	326	702		
17	316	520	574	870	888	529	---	148	387	576		
18	310	1210	550	864	834	448	59	126	583	639		
19	293	1900	517	836	788	467	---	121	375	610		
20	298	1910	418	800	759	417	192	122	342	604		
21	279	1870	494	764	630	415	---	112	372	---		
22	290	1750	488	730	635	472	---	105	479	---		
23	309	1960	479	810	597	510	151	115	580	---		
24	270	2230	478	981	575	427	120	114	451	---		
25	299	1980	467	898	553	392	119	110	416	---		
26	302	1770	524	837	526	297	149	104	403	---		
27	311	1620	570	800	532	330	125	107	539	---		
28	297	1510	576	740	577	304	380	116	523	---		
29	309	----	569	836	515	314	519	222	368	---		
30	246	----	586	835	632	240	268	265	438	---		
31	277	----	567	---	681	---	274	251	---	---		

TABLE VI-7

Lowest and Highest Mean Flows for Period of Record (1915-1973)

Consecutive Days	Mean (cfs)	Variance	St. Deviation
Low Flow			
1 Day	58.98	2,034.75	45.11
3 Day	85.60	2,671.13	51.68
7 Day	99.12	2,622.22	51.21
14 Day	107.60	3,049.63	55.22
30 Day	118.09	3,444.71	58.69
60 Day	135.48	4,147.85	64.40
90 Day	153.89	5,138.72	71.69
120 Day	175.16	6,571.60	81.07
183 Day	215.23	9,187.46	95.85
365 Day	413.37	20,261.16	142.34
High Flow			
1 Day	2,011.67	1,201,260.00	1,096.02
3 Day	1,819.22	919,650.19	958.98
7 Day	1,626.43	730,160.50	854.49
15 Day	1,413.40	463,308.31	680.68
30 Day	1,181.60	296,795.75	544.79
60 Day	956.09	146,168.88	382.32
90 Day	832.05	101,770.19	319.01
120 Day	738.07	78,153.00	279.56
183 Day	622.43	53,839.28	232.03
365 Day	420.16	22,535.28	150.12

USGS gage number 04174500

tracer dye. Unfortunately, these studies indicate that time-of-passage estimations even under conditions usually associated with steady flows are difficult to make due to rather continuous regulation of the impoundments. In addition, calculations using volume displacement/stream discharge assumptions also tend to overestimate the time-of-passage in the impounded reaches. However for this sampling program and for projection purposes, the volume displacement/stream discharge techniques of estimating time-of-passage was the most reliable method available.

Sources of Discharge

The primary inputs to the Huron River in this reach are the five urban storm drains. (Allen, Pittsfield-Ann Arbor, Traver Creek, North Campus and Swift Run Drain) which have been monitored during this evaluation. (See Figure VI-1). Flows for the individual drains were determined during each monitored event (See Section River Sampling). No other major inputs occur in this reach (See Section __ Other Waste Loads).

Other Waste Loads

The Southeast Michigan Council of Governments (SEMCOG) report in their 208 background report(2) that as of 1975, within the Huron River system there are approximately 57 point sources of discharge to the surface water. In addition, there are four discharges to the groundwater of the basin via structures such as seepage lagoons. Of the point source discharging to the Huron River, 17 percent are either municipally owned wastewater plants or small package plants discharging domestic wastewaters. Point sources discharging into the Huron River (or a connecting storm drain) between Argo and Geddes Dam are presented in Table VI-8. Most of these discharges are non-contact cooling water which are considered not to have any significant impact on the water quality of this stretch of the Huron River. The principal point source discharging into the Huron River near this area is the Ann Arbor wastewater treatment plant located just downstream of Geddes Dam with average daily flows of 21 MGD. (1978 value)

WATER QUALITY - LITERATURE

Figures VI-2,3,4,5 summarize most of the available river data for selected parameters at locations upstream of, in the middle of and at the end of the study area. This data represents available wet and dry weather data from the Michigan Department of Natural Resources sampling program (entire period of record), University of Michigan graduate school studies, U.S.G.S. survey, SEMCOG's studies and this NURP study. These different studies are indexed by numbers located on top of the range line. Some studies sampled at two locations within the study area allows for direct comparisons while others were sampled at only one point within the reach. Ranges and mean concentrations are indicated for most of the parameters. It should be noted that the 5 major drains discharge into the Huron River between mile point 48.1 and milepoint 43. As can be seen in Figure VI-2, the pH of the river remains fairly constant for all studies during wet and dry periods. Total suspended solids data found along this reach of the river have mean concentrations that overall hold fairly steady throughout this section of the river. Data available from individual

TABLE VI-8

Industrial Waste Inputs from NPDES Permit Public Notices

Name	Activity	Effluent	Discharge Point
Ann Arbor Veterans Park	Ice Skating Rink	Cooling water non-contact	Storm Drain
Associated Spring Corp.	Spring Manufacturing	Cooling water non-contact	Allen Drain
Climax Molybdinum Co.	Research Lab.	Cooling water non-contact	Ditch to Huron River
Coca Cola Bottling Co.	Soft Drink Bottling	Vehicle wash Water	Pittsfield Drain
Culligan Water Conditioning	Manufacturing water cond. equip.	Process wastewater	Storm Drain
Crystal Optics	Prod. of synthetic gems	Cooling water non-contact	Pittsfield Drain
Environmental Dynamics	Auto engine testing	Cooling water non-contact	Huron River
Federal Mogul	Materials Research	Process waste and non-contact Cooling water	Pittsfield Drain
Ivory Photo Inc.	Photograph Processing	Process rinse water	Storm Drain
Jackson Welding and Supply Co.	Acetylene Prod.	Cooling water non-contact	Storm Drain
Park Davis and Co.	Pharmaceutical Research	Cooling water non-contact	Storm Drain

Reference: Huron River Water Quality Study In Vicinity of Ann Arbor, Michigan. Department of Environmental and Industrial Health, School of Public Health, University of Michigan, 1978.

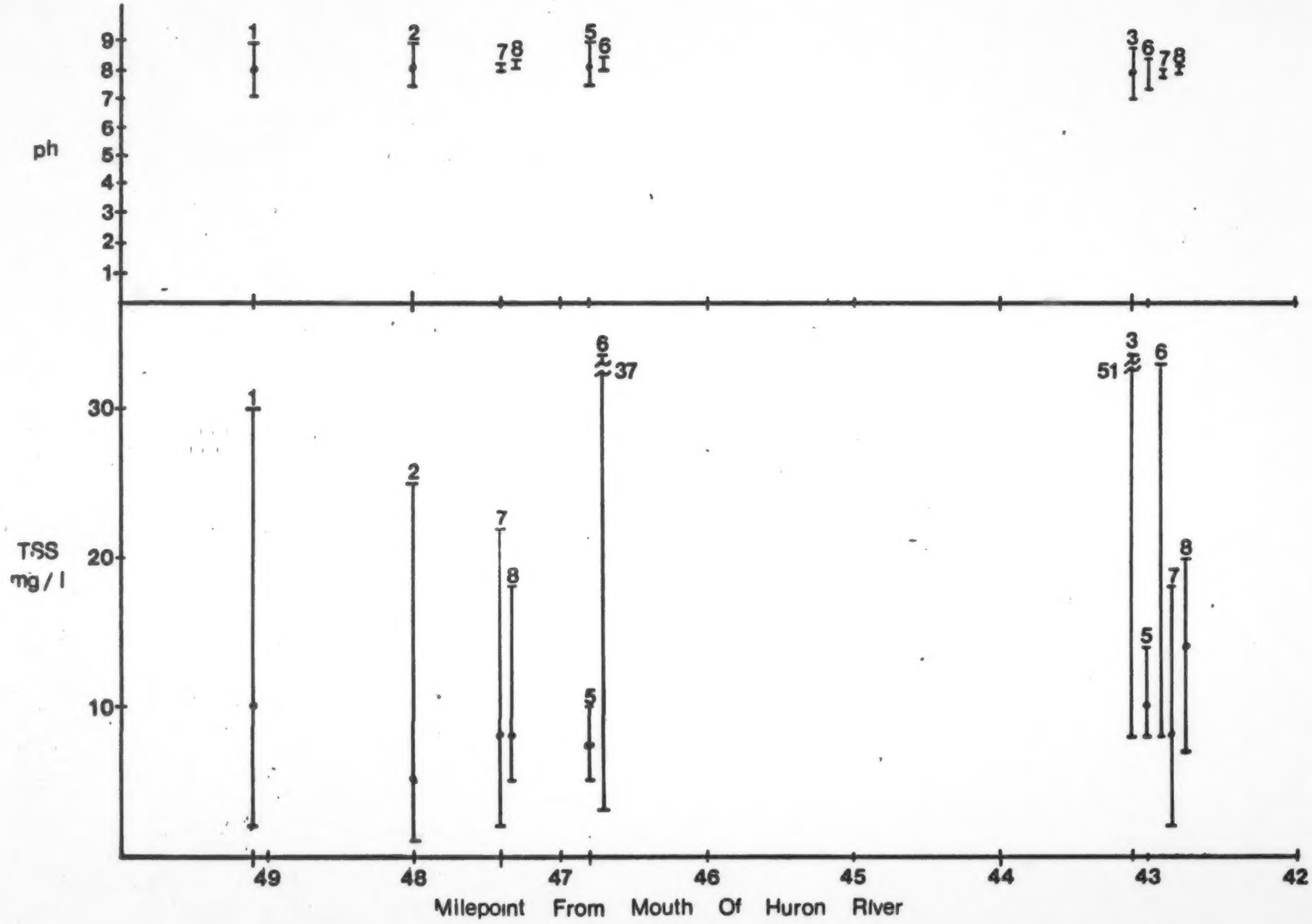


Figure VI-2 Historical Data

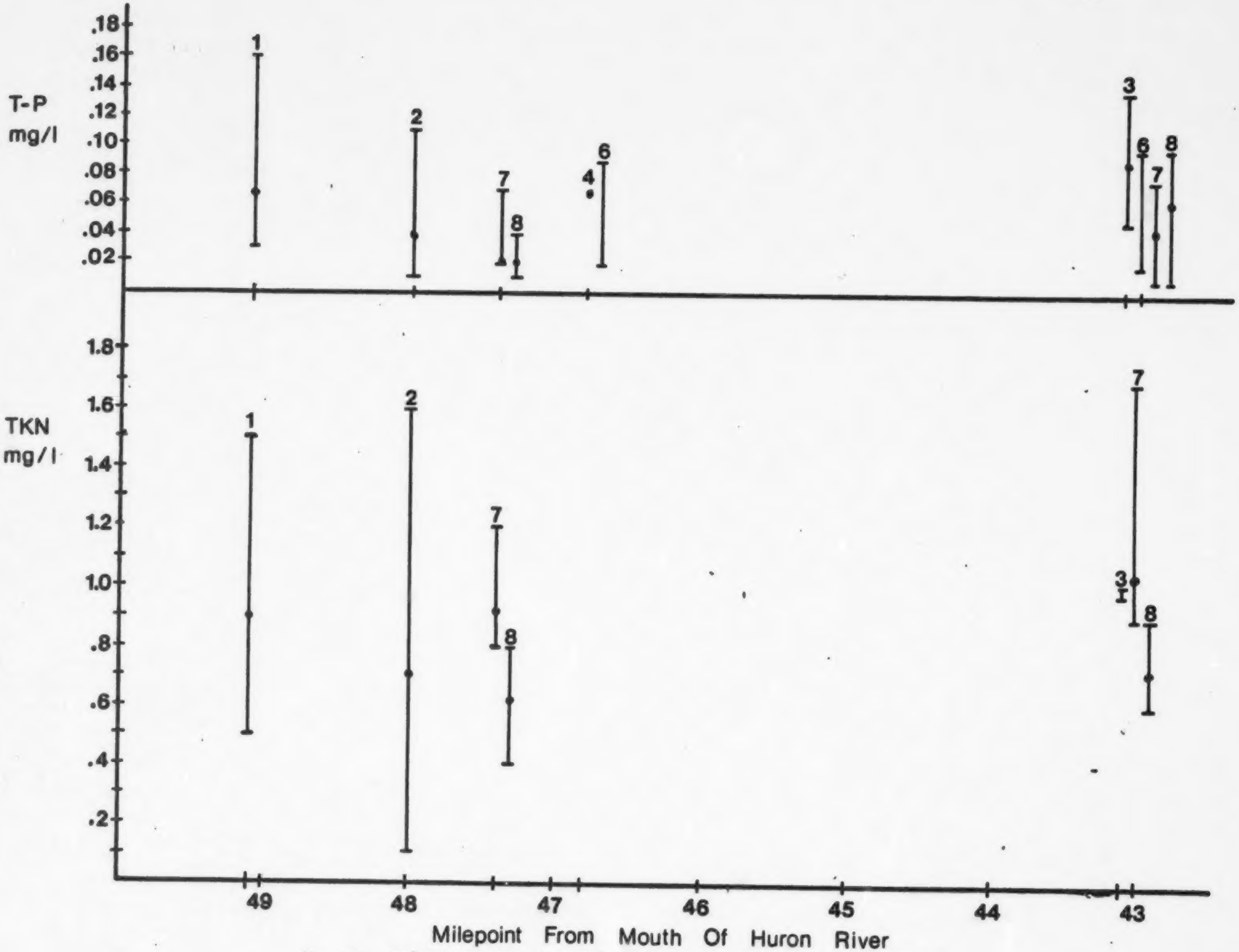


Figure VI-3 Historical Data-Nutrients

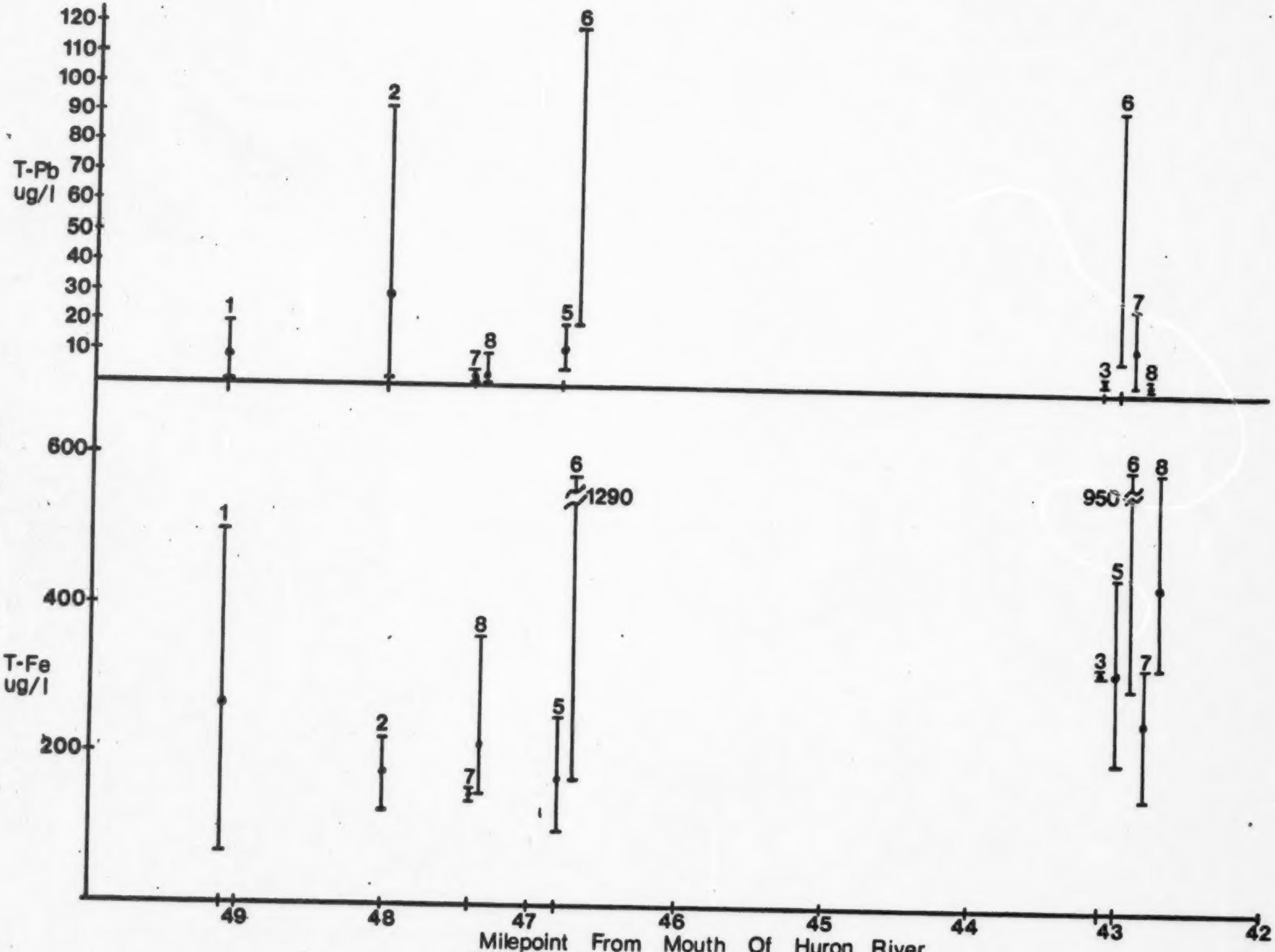


Figure VI-4 Historical Data-Metals

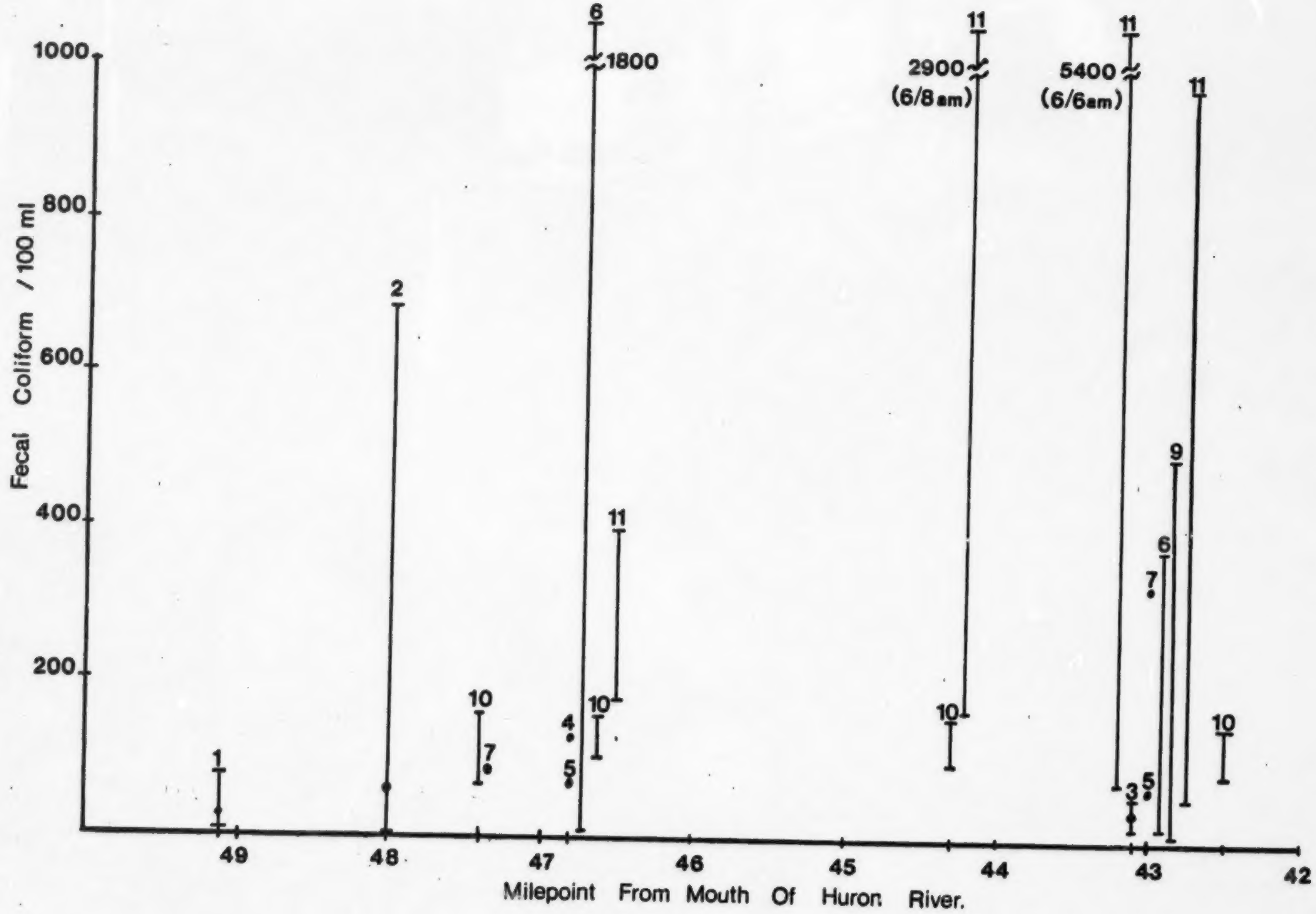


Figure VI-5 Historical Data-Fecal Coliform

KEY FOR FIGURES VI-2,3,4,5

Mile Point	Sampling Location
49.1	Barton Pond - City of Ann Arbor Water Intake
48	Huron River at Huron Bridge Park
47.4	Argo Dam
46.8	Wall Street U.S.G.S. Gage
44.3	Gallup Park Bridge
43.1	Geddes Pond - City of Ypsilanti Auxillary Water Intake
43.0	Geddes Dam
42.5	Sewage Treatment Plant Bridge

Number	Information Source
1	MDNR - Storet - (period of record).
2	MDNR - Storet - (period of record).
3	MDNR - Storet - (Period of record).
4	U.S.G.S. study 1976.
5	SEMCOG - dry weather 1977.
6	SEMCOG - wet weather 1977.
7	ENCOTEC Feb. 1979 snow melt.
8	ENCOTEC August 1979 wet weather.
9	U. of M. School of Public Health, week of May 8, 1978. Dry Weather.
10	U. of M. School of Public Health, week of May 22, 1978. Dry weather.
11	U. of M. School of Public Health, week of June 5, 1978. (Dry weather except for Rain June 7, A.M.)

events where two points are sampled shows a slight increase in the mean concentration at the lower end of the reach (Geddes Dam). Total Kjeldahl nitrogen mean concentrations along this section remain fairly constant from Argo to Geddes Dam. Total iron data indicates a slight increase in the event mean concentrations at Geddes Dam when compared to event mean concentrations upstream before the impoundment. Figure VI-5 shows the fecal data available on the river in this reach. An increase in mean concentrations can be seen occurring after the Allen Drain input (milepoint 47.3) and remaining at high levels throughout the downstream section of the study reach.

The largest data base available on the general water quality of the river in this section is that from the Michigan Department of Natural Resources river sampling program. This Storet data presents data for the entire period of record at three points along the river. Two stations upstream of Argo Dam provides historical data on the quality of water entering the study reach and one station in Geddes Pond provides data on the quality of water leaving the study reach. Table VI-9,10,11 summarize in statistical form selective parameters for the entire period of record at these stations. A full listing of the entire statistical printout for all of the parameters sampled at these stations is presented in the separate data report. Additional wet and dry weather data for this reach of the river is provided by the SEMCOG studies with selected parameter results illustrated in Figures VI-2,3,4,5. A complete listing of the results collected by SEMCOG is also presented in the separate data report.

Generally it can be seen from the historical data available that on a long term approach the water quality of

TABLE VI-9

STORET DATA

STATION: Water Intake from Huron River, City of Ann Arbor DATE: Period of Record

Average Concentration	No.	Mean	Variance	Stan. Dev.	Max.	Min.	Beg. Date	End Date
TSS mg/l:	11	10	58	7.6	30	2	9/2/70	5/30/79
Total Residue mg/l:	11	390	7,900	89	650	320	9/2/70	5/30/79
Total Alkalinity mg/l:	10	210	1,500	39	310	160	3/23/71	5/30/79
BOD mg/l:								
NO_3N mg/l:	4	0.20	0.05	0.21	0.45	0	9/2/70	5/15/72
TKN mg/l:	5	0.87	0.13	0.36	1.5	0.58	10/21/75	5/30/79
SKN mg/l:								
TP mg/l:	11	0.07	0.002	0.04	0.16	0.03	9/2/70	5/30/79
SP mg/l:								

NO_3N - Nitrate
TSS - Total Suspended Solids
BOD - Biological Oxygen Demand
TP - Total Phosphorus
TKN - Total Kjeldahl Nitrogen
SKN - Soluble Kjeldahl Nitrogen
SP - Soluble Phosphorus

TABLE VI-9 (Continued)

STORET DATA

STATION: Water Intake from Huron River, City of Ann Arbor DATE: Period of Record

Average Concentration	No.	Mean	Variance	Stand. Dev.	Max	Min.	Beg. Date	End Date
COD mg/l:								
T-FE ug/l:	4	270	39,000	200	500	83	6/21/76	5/30/79
S-FE ug/l:	6	56	5,900	77	210	6.0	5/15/72	6/15/77
T-Pb ug/l:	4	9.5	60	7.7	17	1	6/21/76	5/30/79
S-Pb ug/l:	7		37	6.0	15	0	9/2/70	6/15/77
T-Zn ug/l:	4	14	70	8.3	22	5	6/21/76	5/30/79
T-Cr ug/l:	4	4.8	4.2	2.1	7.0	3.0	6/21/76	5/30/79
T-Cd ug/l:	4	0.92	0.38	0.62	1.6	0.1	6/21/76	5/30/79
G&O mg/l:								

COD - Chemical Oxygen Demand
T-FE - Total Iron
S-FE - Soluble Iron
T-Pb - Total Lead
S-Pb - Soluble Lead
T-Zn - Total Zinc
T-Cr - Total Chromium
T-Cd - Total Cadmium
G&O - Grease and Oil

TABLE VI-10

STORET DATA

STATION: Huron River at Huron Bridge Park, Ann Arbor Township DATE: Period of Record

Average Concentration	No.	Mean	Variance	Stan. Dev.	Max.	Min.	Beg. Date	End Date
TSS mg/l:	77	5.5	23	4.7	24	1	4/16/75	8/25/81
Total Residue mg/l:	77	380	1,100	33	530	300	4/16/75	8/25/81
Total Alkalinity mg/l:	48	200	220	15	230	160	4/16/75	7/21/81
BOD mg/l:	76	2.5	1.3	1.2	7.8	0.5	4/16/75	8/25/81
NO_3N mg/l:								
TKN mg/l:	24	0.77	0.07	0.27	1.6	0.09	11/28/78	8/25/81
SKN mg/l:								
TP mg/l:	77	0.04	0.0003	0.02	0.11	0.01	4/16/75	8/25/81
SP mg/l:								

NO_3N - Nitrate
TSS - Total Suspended Solids
BOD - Biological Oxygen Demand
TP - Total Phosphorus
TKN - Total Kjeldahl Nitrogen
SKN - Soluble Kjeldahl Nitrogen
SP - Soluble Phosphorus

TABLE VI-10 (Continued)

STORET DATA

STATION: Huron River at Huron Bridge Park, Ann Arbor Bridge Park, Ann Arbor Township DATE: Period of Record

Average Concentration	No.	Mean	Variance	Stan. Dev.	Max.	Min.	Beg. Date	End Date
COD mg/l:	51	18	15	3.9	31	8.3	4/16/75	8/25/81
T-FE ug/l:	5	180	1,800	42	220	130	9/9/76	9/29/80
S-FE ug/l:	1	22			22	22	8/28 75	8/28/75
T-Pb ug/l:	4	31	1,700	41	91	2	9/9/76	9/29/80
S-Pb ug/l:	1	20			20	20	8/28/75	8/28/75
T-Zn ug/l:	5	9.6	17	4.2	16	5	9/9/76	9/29/80
T-Cr ug/l:	3	3.7	0.33	0.58	4	3	9/9/76	9/25/78
T-Cd ug/l:	2	1.6	1.4	1.2	2.5	0.8	9/9/76	8/9/77
G&O mg/l:								

COD - Chemical Oxygen Demand
T-FE - Total Iron
S-FE - Soluble Iron
T-Pb - Total Lead
S-Pb - Soluble Lead
T-Zn - Total Zinc
T-Cr - Total Chromium
T-Cd - Total Cadmium
G&O - Grease and Oil

TABLE VI-11

STORET DATA

STATION: Water Intake from Huron River, City of Ypsilanti   DATE: Period of Record

Average Concentration	No.	Mean	Variance	Stan. Dev.	Max.	Min.	Beg. Date	End Date
TDS mg/l:	6	22	300	17	51	8	9/2/70	6/21/76
Total Residue mg/l:	6	420	1,800	42	500	370	9/2/70	6/21/76
Total Alkalinity mg/l:	5	210	1,000	32	260	180	3/23/71	6/21/76
BOD mg/l:								
NO_3N mg/l:	3	0.12	0.01	0.10	0.2	0	9/2/70	5/15/72
TKN mg/l:	1	1.0	---	---	1.0	1.0	6/21/76	6/21/76
SKN mg/l:								
TP mg/l:	6	0.09	0.001	0.04	0.14	0.05	9/2/70	6/21/76
SP mg/l:								

NO_3N - Nitrate
TSS - Total Suspended Solids
BOD - Biological Oxygen Demand
TP - Total Phosphorus
TKN - Total Kjeldahl Nitrogen
SKN - Soluble Kjeldahl Nitrogen
SP - Soluble Phosphorus

TABLE VI-11 (Continued)

STORET DATA

STATION: Water Intake from Huron River, City of Ypsilanti   DATE: Period of Record

Average Concentration	No.	Mean	Variance	Stan. Dev.	Max	Min.	Beg. Date	End Date
COD mg/l:								
T-FE ug/l:	1	330	---	---	330	330	6/21/76	6/21/76
S-FE ug/l:	4	280	210,000	460	970	34	5/15/72	6/21/76
T-Pb ug/l:	1	4.0	---	---	4.0	4.0	6/21/76	6/21/76
S-Pb ug/l:	5	4.8	19	4.3	10	0	9/2/70	6/21/76
T-Zn ug/l:	1	34	---	---	34	34	6/21/76	6/21/76
T-Cr ug/l:	1	4.0	---	---	4.0	4.0	6/21/76	6/21/76
T-Cd ug/l:	1	0.6	---	---	0.6	0.6	6/21/76	6/21/76
G&O mg/l:								

COD - Chemical Oxygen Demand
T-FE - Total Iron
S-FE - Soluble Iron
T-Pb - Total Lead
S-Pb - Soluble Lead
T-Zn - Total Zinc
T-Cr - Total Chromium
T-Cd - Total Cadmium
G&O - Grease and Oil

the Huron River has remained fairly constant over many years under a variety of conditions. However, short term water quality changes can be noticed after storm events.

DATA COLLECTION

As described earlier in this report, five stations for the measurement of flow and collection of composite water samples were established at the outlets of each of the five drainage districts discharging into the Geddes Pond Area of the Huron River. In addition, two stations were established on the river itself, one upstream of the drains at Argo Dam and one downstream at Geddes Dam. The drain outlet stations were located as near the mouth of the drain as possible without being influenced by backwater effects. Each station consisted of a continuous level recorder and a Manning automatic sampler for taking discrete samples. Equipment was housed in steel boxes for security. Float switches were used to activate the sampling equipment. The sampling stations for the river were established at Argo and Geddes Dam. Automatic sampling equipment was placed on the dam structure and samples were collected where the water passed through the dams.

Discrete samples were collected throughout the runoff period. Flow data, obtained from the continuous level recorders, was then used to composite the discrete samples on a flow proportionate basis. Samples which were composited, were either analyzed immediately by the laboratory or preserved by approved USEPA procedures. All compositing and preservation were performed in the laboratory as all stations were in close proximity to the offices. Analytical procedures followed approved methods. Quality control and quality assurance procedures are presented in Appendix I.

Results

The Huron River and five major drain outlets were sampled twice during this study. A snow melt survey occurred in February 1979 and a summer rain event was monitored in August of 1979.

Huron River and Drain Outlet Snow Melt Survey

The Huron River and five drain outlets were sampled during a major snow melt period between February 22 and February 26, 1979. The weather began to warm into the low 30's (°F) during the week. River sampling began on February 22 and continued until February 26. On February 23 the temperature rose to forty degrees (°F) and sampling of the five drain outlets was performed. The weather turned colder on the night of February 23 and remained below freezing until February 26, 1979.

The flow measurements and sampling of the five drain outlets were performed manually and covered approximately a 24 hour period. Figures VI-6 to VI-10 show the runoff hydrographs for the drain outlets. Grab samples collected throughout the runoff period, were composited based on flow for each of the drain outlet stations. River sampling was performed using automatic samplers, with samples being composited to represent periods before, during and after the runoff event. A total of five composite samples at each river station were collected for subsequent chemical analyses.

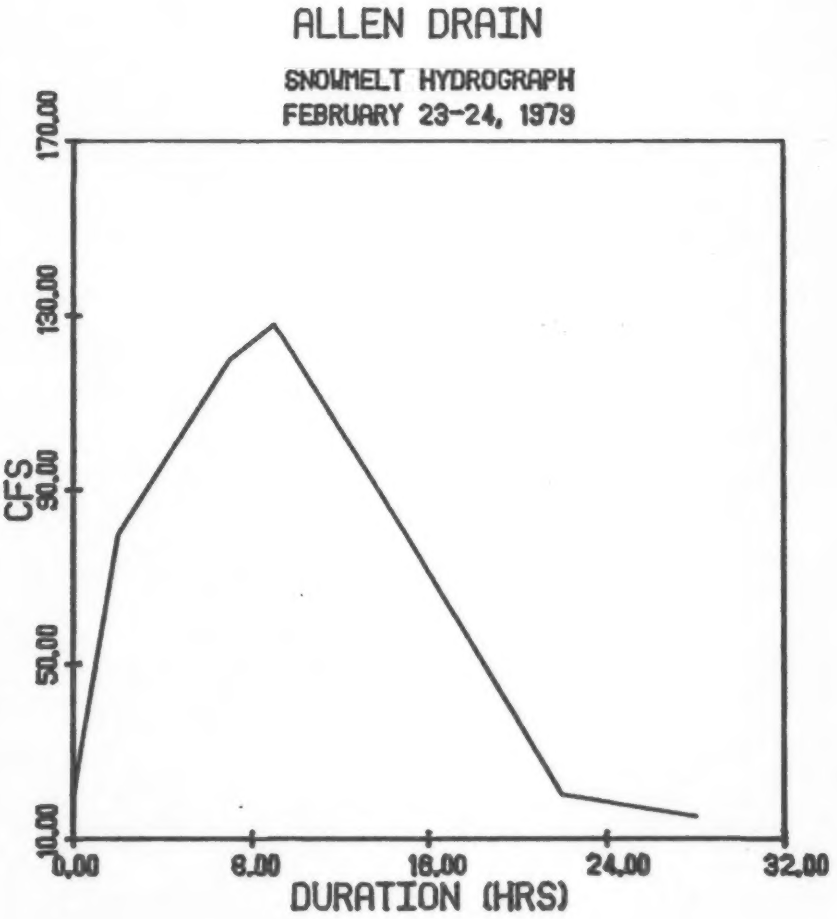

ALLEN DRAIN
SNOWMELT HYDROGRAPH
FEBRUARY 23-24, 1979
CFS
170.00
130.00
90.00
50.00
10.00
0.00
8.00
16.00
24.00
32.00
DURATION (HRS)

Figure VI-6

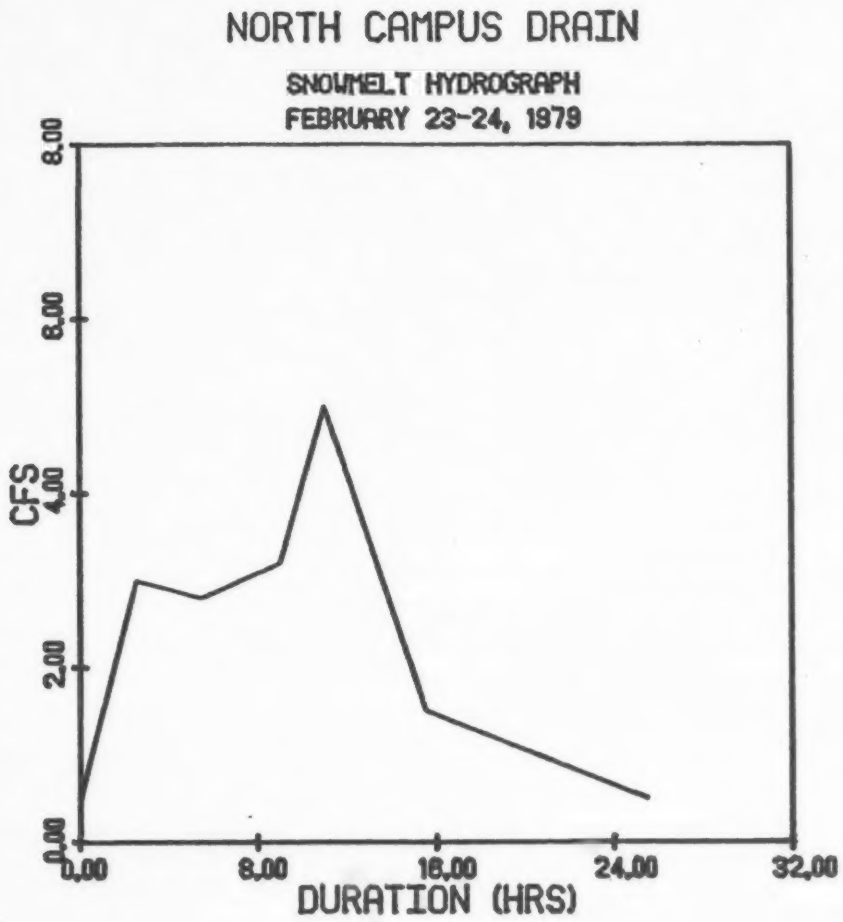
NORTH CAMPUS DRAIN
SNOWMELT HYDROGRAPH
FEBRUARY 23-24, 1979
CFS
0.00
2.00
4.00
6.00
8.00
0.00
8.00
16.00
24.00
32.00
DURATION (HRS)

Figure VI-7

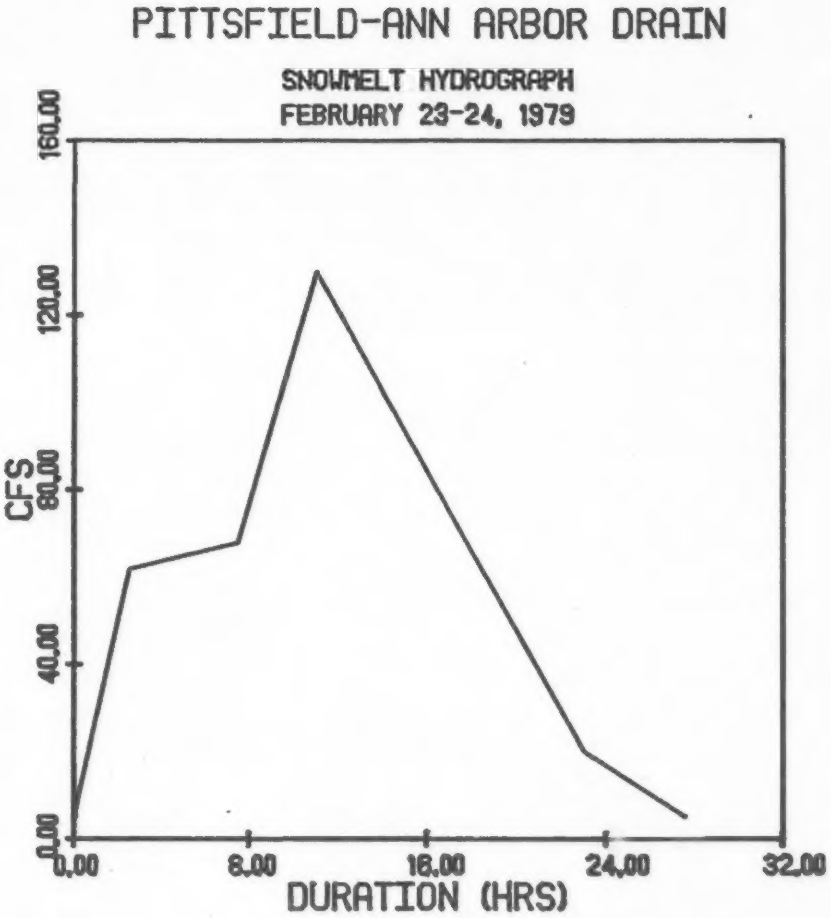

PITTSFIELD-ANN ARBOR DRAIN
SNOWMELT HYDROGRAPH
FEBRUARY 23-24, 1979
CFS
0.00
40.00
80.00
120.00
160.00
0.00
8.00
16.00
24.00
32.00
DURATION (HRS)

Figure VI-8

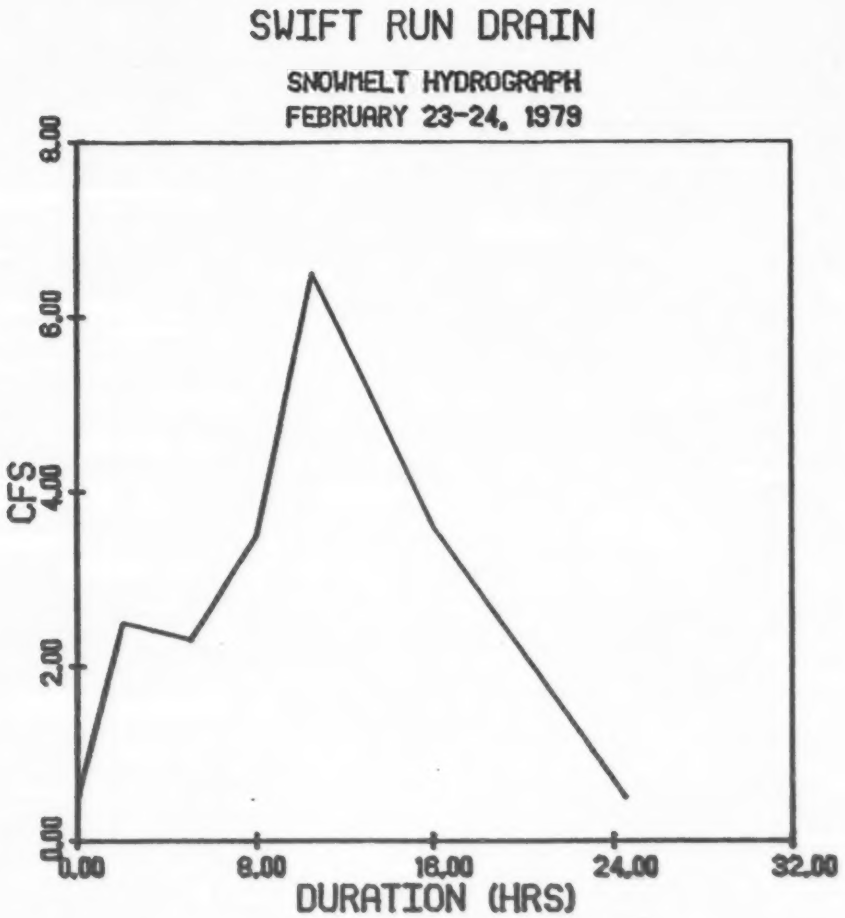

SWIFT RUN DRAIN
SNOWMELT HYDROGRAPH
FEBRUARY 23-24, 1979
CFS
0.00
2.00
4.00
6.00
8.00
0.00
8.00
16.00
24.00
32.00
DURATION (HRS)

Figure VI-9

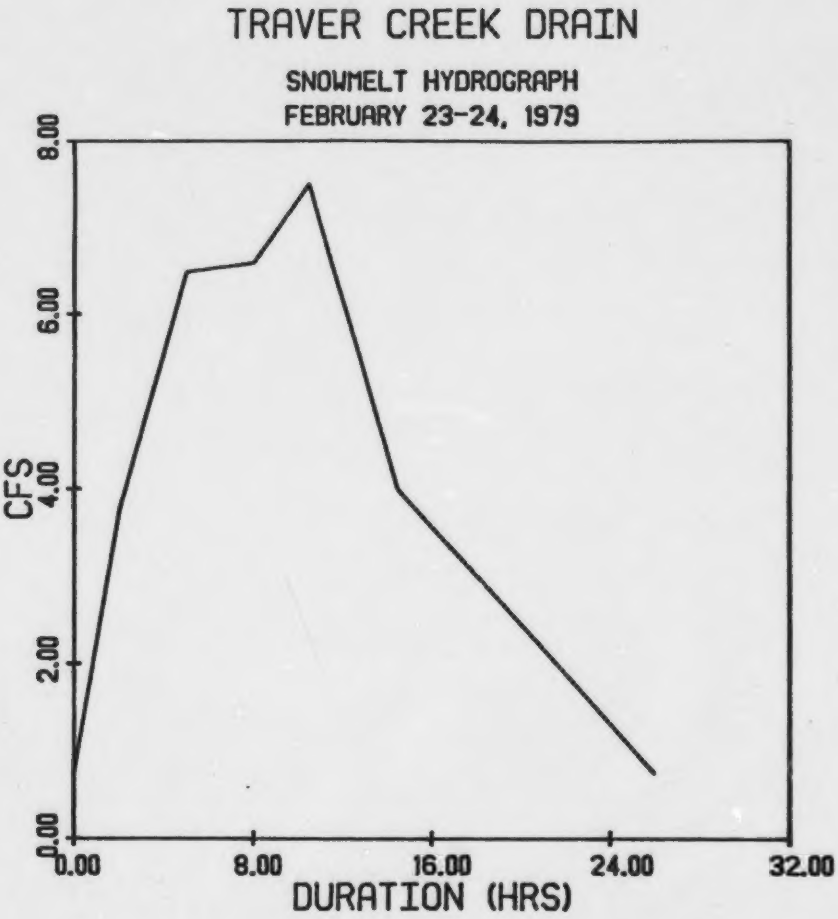

TRAVER CREEK DRAIN
SNOWMELT HYDROGRAPH
FEBRUARY 23-24, 1979
CFS
0.00
2.00
4.00
6.00
8.00
0.00
8.00
16.00
24.00
32.00
DURATION (HRS)

Figure VI-10

The pollutant loads (solids, nutrients and metals) measured in the drains are shown in Tables VI-12. In reviewing this data, it can be seen that the largest flow and loads are from Allen Drain followed by the Ann Arbor-Pittsfield Drain. This essentially follows the same pattern as the land use/cover for the drains with Allen Drain representing the heart of the city and Ann Arbor-Pittsfield the largest drain in the City. The flow from these two drains was substantially higher during this period. Observations indicated that this was due to the large amount of snow melted along the roadways which constituted a larger percentage of area in these two drains as compared with the other drains. In addition, each of the other drains Swift Run, Traver Creek, and North Campus, have substantial amounts of open undeveloped area in the upper portion of the districts. These areas were still frozen during the runoff survey and contributed very little to the total flow. North Campus Drain and Swift Run Drain were partially frozen in their entire length throughout the sampling period. It was quite apparent following the survey that additional runoff in the three smaller open drains would occur during subsequent warm weather and that the runoff duration would be spread over a larger period of time than the more developed and/or enclosed drains. The melt event monitored here represented the first major and largest snow melt of the season and virtually cleared the main street areas of snow. Thus, the high loads of Allen and Pittsfield-Ann Arbor Drains represent a major portion of the snow melt from impervious surfaces in these districts. The other three drains were receiving runoff but not nearly as high a total amount in relationship to their size.

When looking at the data on a pounds/acre basis, Allen Drain and Pittsfield-Ann Arbor Drain clearly show more

TABLE VI-12

Pollutant Loads
Snow Melt Survey
Ann Arbor, Michigan

February 23, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft.)	5,432	5,389	235	338	200
pH	(S.U.)	7.85	7.94	7.77	7.99	7.89
Total Dissolved Solids	lbs.	680,300	467,800	39,000	27,700	21,200
Total Suspended Solids	lbs.	70,000	39,000	1,300	3,400	700
Biological Oxygen Demand	lbs.	8,500	5,700	450	690	200
Total Kjeldahl Nitrogen	lbs.	1,400	500	32	50	22
Soluble Kjeldahl	lbs.	1,060	400	29	31	15
Nitrate	lbs.	700	400	36	37	8
Total Phosphorus	lbs.	170	63	2	5	1.3
Soluble Phosphorus	lbs.	47	10	0.6	1.7	0.1

TABLE VI-12 (Continued)

Metal Loads
Snow Melt Survey
Ann Arbor, Michigan

February 23, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft)	5,432	5,389	235	338	200
Iron	lbs.	1,800	970	33	60	20
Soluble Iron	lbs.	13	3	1.2	0.4	0.4
Lead	lbs.	138	46	0.8	4.1	0.9
Soluble Lead	lbs.	2.7	0.7	0.07	0.12	0.02
Zinc	lbs.	193	64	2.6	5.3	0.7
Chromium	lbs.	26.8	19.1	0.4	0.8	0.2
Cadmium	lbs.	4.7	0.5	0.02	0.03	0.002
Copper	lbs.	33.9	12.8	0.3	0.5	0.2
Nickel	lbs.	10.8	3.4	0.2	0.5	0.09

runoff and loading per acre than the three other drains (See Chapter V). These higher values per acre again reflects the more densely developed areas, greater imperviousness and more commercial/industrial land uses that are typical in these two drainage districts.

Table VI-13 presents the event mean concentrations (EMC) for selected representative parameters for all of the drains. When comparing EMC's of different parameters between the drain outlets, Allen Drain still exhibits the highest values. However in contrast to the loading values, the Traver Creek drain outlet (not the Pittsfield-Ann Arbor drain outlet) consistently shows higher EMC's than found in the remaining three drains.

The event mean concentrations of the data collected at the river stations during the river survey are shown in Table VI-14. Sampling began the morning before the main runoff occurred and continued for a four day period. The upstream flow at Argo Dam remained fairly constant during the period (200-225 cfs) increasing only slightly during the third day. This fairly constant flow was also reflected in the water quality data. Most of the water quality measures remained steady with only suspended and dissolved solids levels showing a somewhat decreasing trend. This steady water qualiy condition is influenced by the two large ponds upstream (Argo Pond and Barton Pond) and a very small amount of developed land immediately upstream. The flow at Geddes Dam showed the influence of the runoff waters as the flow increased substantially during and after the event. This influence is also reflected in the consistently higher EMC's found at Geddes Dam when compared to values measured at Argo Dam. Water quality changes between individual composites also show some of the effects of the drain inputs

TABLE VI-13

Event Mean Concentrations
Drain Outlets
Snow Melt Survey

February 23, 1979

Parameter	Unit	Allen Drain	Pittsfield Ann Arbor	North Campus	Swift Run	Traver Creek
Flow	Cu. Ft.	5,432,000	5,389,000	200,000	235,000	338,000
TDS	mg/l	2,020	1,400	1,710	2,700	1,320
TSS	mg/l	305	117	53	93	163
TKN	mg/l	4.4	1.5	1.7	2.3	2.5
SKN	mg/l	3.4	1.2	1.2	2.0	1.5
TP	mg/l	0.54	0.19	0.10	0.17	0.25
SP	mg/l	0.14	0.03	0.01	0.04	0.08
BOD	mg/l	37	17	15	32	33
T-Fe	mg/l	5.6	2.9	1.5	2.4	3.1
S-Fe	mg/l	0.04	0.01	0.03	0.08	0.02
T-Pb	mg/l	0.43	0.14	0.07	0.005	0.17
S-Pb	mg/l	0.008	0.002	0.002	0.005	0.006

TABLE VI-14

Event Mean Concentrations
Argo Dam/Geddes Dam

February, 1979   Snow Melt

Parameter	Argo Dam (mg/l)	Geddes Dam (mg/l)
TSS	7.8	8.6
TDS	429	536
BOD	<2	<3
NO_3-N	0.41	0.56
TKN	0.89	1.0
SKN	0.56	0.81
TP	0.02	0.04
SP	<0.02	<0.02
T-Fe	0.13	0.24
S-Fe	0.01	0.02
T-Pb	0.001	0.01
S-Pb	0.001	<0.001
T-Zn	0.009	0.03
T-Cr	0.02	0.02
T-Cd	<0.0001	<0.0001
T-Cu	0.002	0.004
T-Ni	<0.001	0.001

particularly for Kjeldahl nitrogen, iron, lead, and zinc (See Separate Data Report). The levels of these constituents increased noticeably in the samples collected immediately following the runoff period. The particle size data (Table VI-15,16) also shows a slight shift in distribution in the February 23 and 24 samples. This appears to reflect the large amounts of solids discharged by the drains.

Summaries of the pollutants entering and leaving the impoundment are presented in Table VI-17. These summary tables are based on total loadings entering (from upstream sources and drain outlets) and leaving the study area during the runoff period. The loadings presented included both baseflow conditions and loadings from the snow melt period. Individual parameter values for each composite are presented in the Separate Data Report. Removal efficiencies of over fifty percent are seen for total suspended solids, total iron, lead, zinc, cadmium, copper and nickel. These high removal efficiencies can be attributed to sedimentation processes occurring in Geddes Pond. Nutrient removal is not experienced although it would not be expected in parameters that are found mostly in the soluble state as is the case with kjeldahl nitrogen. Fecal coliform data for the snow melt survey is presented in Table VI-18.

Huron River and Drain Outlet - Summer Survey

Prior to the successful drain outlet and river survey, a smaller rainfall occurred on August 4-5, 1979 (0.3 inches). Water quality sampling was begun, but the survey was stopped because of the small amount of rain. A minimum of 0.5 inches of rain was desired to provide good runoff

TABLE VI-15

PARTICLE SIZE DISTRIBUTION
Snow Melt Survey

February 23, 1979

MICRON SIZE	Allen Drain Conc. mg/1	Allen Drain Load lb.	Pittsfield-Ann Arbor Drain Conc. mg/1	Pittsfield-Ann Arbor Drain Load lb.	Swift Run Drain Conc. mg/1	Swift Run Drain Load lb.	Traver Creek Drain Conc. mg/1	Traver Creek Drain Load lb.	North Campus Drain Conc. mg/1	North Campus Drain Load lb.
>60	189	64,000	71	24,000	67	980	114	2,400	36	450
10-60	67	22,700	28	9,400	12	180	34	720	9	110
4-10	40	13,600	13	4,400	9	130	10	210	7	90
<4	9	3,000	5	1,700	5	75	5	100	2	25

TABLE VI-16

PARTICLE SIZE DISTRIBUTION

LOCATIONS: Huron River Stations DATE: February 1979

	MICRON SIZE	Feb. 22-23 Conc. mg/l	Feb. 22-23 Load lb.	Feb. 23 Conc. mg/l	Feb. 23 Load lb.	Feb. 24 Conc. mg/l	Feb. 24 Load lb.	Feb. 25 Conc. mg/l	Feb. 25 Load lb.
Argo Dam	>60	---	---	---	---		+		+
	10-60	---	---	---	---				
	4-10	9	9,800	10	4,300				
	<4	9	9,800	10	4,300				
Geddes Dam	>60	---	---	1	700	---	---	---	---
	10-60	9	10,000	4	2,800	3	3,600	2	2,700
	4-10	4	4,500	1	700	1	1,200	3	4,000
	<4	4	4,500	1	700	4	4,700	5	6,700

+ (Other Argo Dam samples too low to measure.)

* NOTE: This data provides an indication of particle distribution; however, because of the low TSS levels initially, a large scatter in the data was observed. This should be noted when utilizing the data.

TABLE VI-17

POLLUTANTS ENTERING AND DISCHARGED FROM
GEDDES POND, HURON RIVER

February 22-26, 1979

	Volume Cu. Ft.	Total Suspended Solids lbs.	Dissolved Solids lbs.	Total Phosphorus lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble TKN lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Iron lbs.	Soluble Iron lbs.
Upstream River Water (Argo Dam)	$74 x 10^6$	36,000	1,983,000	107	1,900	4,100	2,600	<5	<5	600	65
Storm Drains (5)	$11.6 x 10^6$	114,000	1,015,000	242	1,200	2,000	1,500	191	4	2,880	20
Discharged From Geddes Pond	$89 x 10^6$	48,000	2,980,000	196	3,200	5,800	4,500	75	<6	1,320	110
Pollutant Remaining in Geddes Pond		102,000	(18,000)	153	(-100)	300	(-400)	116	>0	2,160	(-25)
Percent of Drain Input Remaining in Geddes Pond		89	x	63	x	15	(-27)	61		75	(-125)

NOTE: Loads for river water at Argo and Geddes Dam represent 4 days of flow.
Drain inputs are for approximately 24-hour-period of snow melt runoff.

x = 0±10%

TABLE VI-17 (Continued)

Metals Entering and Discharged From Geddes Pond, Huron River

February 22-26, 1979

	Volume Cu. Ft.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Total Copper lbs.	Total Nickel lbs.
Upstream River Water (Argo Dam)	74×10^6	40.5	70	<0.46	9.7	<4.6
Storm Drains (5)	11.6×10^6	266	47	5.2	48	15
Total	85.6×10^6	306	117	5.6	57.7	19.6
Discharged From Geddes Pond	89×10^6	156	110	<0.56	24	7.6
Pollutant in Geddes Pond (Mass Balance)		150	7	5	34	12
Percent of Drain Input Remaining		49	15	96	70	80

TABLE VI-18

Fecal Coliform
Snow Melt Survey

February, 1979

Station	Date/Time		Instantaneous Flow (cfs)	Fecal Coliform (CFU/100)
Pittsfield - Ann Arbor Drain Outlet	2/23/79	14:30	67	11,000
Allen Drain Outlet	2/23/79	14:30	110	11,000
Traver Creek Drain Outlet	2/23/79	14:30	6.4	52,000
Swift Run Drain Outlet	2/23/79	14:30	3.3	1,200
North Campus Drain Outlet	2/23/79	14:30	3.1	1,200
Argo Dam	2/23/79	14:30	225	90
Geddes Dam	2/24/79	14:30	231	330

conditions from all drains to the river. Samples from three drains (Pittsfield-Ann Arbor, Swift Run and Traver Creek) were submitted to the laboratory for analyses of suspended solids and phosphorus. The data from this brief survey is shown in Table VI-19.

The summer water quality survey was performed during the period of August 17 through August 27. Composite samples of the five drain outlets were collected during the period August 17 through August 19. The Huron river was sampled for a ten day period of August 17 through the 27th at both Argo and Geddes Dam.

Rainfall began on the morning of August 17 and continued for approximately 26 hours. Three periods of more intense rain occurred during the event with light rain or drizzle occurring in the intermediate times. Total rainfall varied considerably between the northern drainage districts and the southern districts. The University of Michigan station and our nearby manual station located in the northern area recorded a total rainfall of 0.93 inches and 0.92 inches, respectively, while our manual station near the southern districts recorded 1.73 inches. An intermediate station in the Allen Drain District recorded 1.4 inches of rain. Inspection of the rainfall records at each station shows the difference in rainfall totals was primarily due to the amount of rain which fell at approximately 2:00 a.m. on August 18. The rainfall amounts at all stations were very close for the entire day on August 17 and for the period after 7:00 a.m. on August 18. However, the overnight amounts differed between the north station and south station by 0.7 inches. The rain gages in the northern area (U of M weather station, one manual gage) are in the immediate area (within one mile) of the North Campus and Traver Drains.

TABLE VI-19

ABBREVIATED SURVEY OF DRAIN OUTLETS, WASHTENAW COUNTY. MICHIGAN

August 4-5, 1979

Total Rainfall - 0.3 inches

Type of Rain - Thunder showers and showers

	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain
Discharge (1000 cu. ft.)	1,108	120	331
Total Suspended Solids (TSS)	15,000	1,120	930
Total Phosphorus (T-P)	18.6	2.80	3.5
Soluble Phosphorus (S-P)	7.6	0.4	1.4

The middle manual station is in the Allen drainage district and the southern station (1.73 inches, rainfall) is in the Ann Arbor-Pittsfield district and adjacent to the Swift Run District.

The runoff hydrographs for each of the five drains are presented in Figures VI-11 - V1-15. The three peaks which occurred during the runoff event are quite evident for each drain and correspond to the three peak rainfall periods during the 26 hour storm event. Samples were collected during the runoff event with the first composite sample representing the first rise and fall of the hydrograph and the second sample collected during the second and third runoff responses. Subsequent samples represented the tail portion of the curve and background conditions.

The pollutant loads measured in the drains are shown in Table VI-20. A general review of these tables shows that the highest loads are originating from the Allen and Pittsfield-Ann Arbor Drains. These higher loadings are not just due to the fact the basins are larger, but these two districts generally have higher concentration of most pollutants and have substantially more runoff and load on a per acre basis (Chapter V). The higher runoff volumes per acre reflects the more densely developed areas, greater imperviousness, more commercial/industrial usage, etc. A good example of this is shown in the total suspended solids data. Allen and Pittsfield-Ann Arbor Drains discharged 14 pounds per acre and 22 pounds per acre of total suspended solids, respectively. Swift Run, Traver Creek and North Campus Drains discharged 2.3, 2.2 and 0.37 pounds of total suspended solids per acre. Another example of this loading difference between drains (i.e. land uses) is shown in the total lead data. Allen and Pittsfield-Ann Arbor Drains,

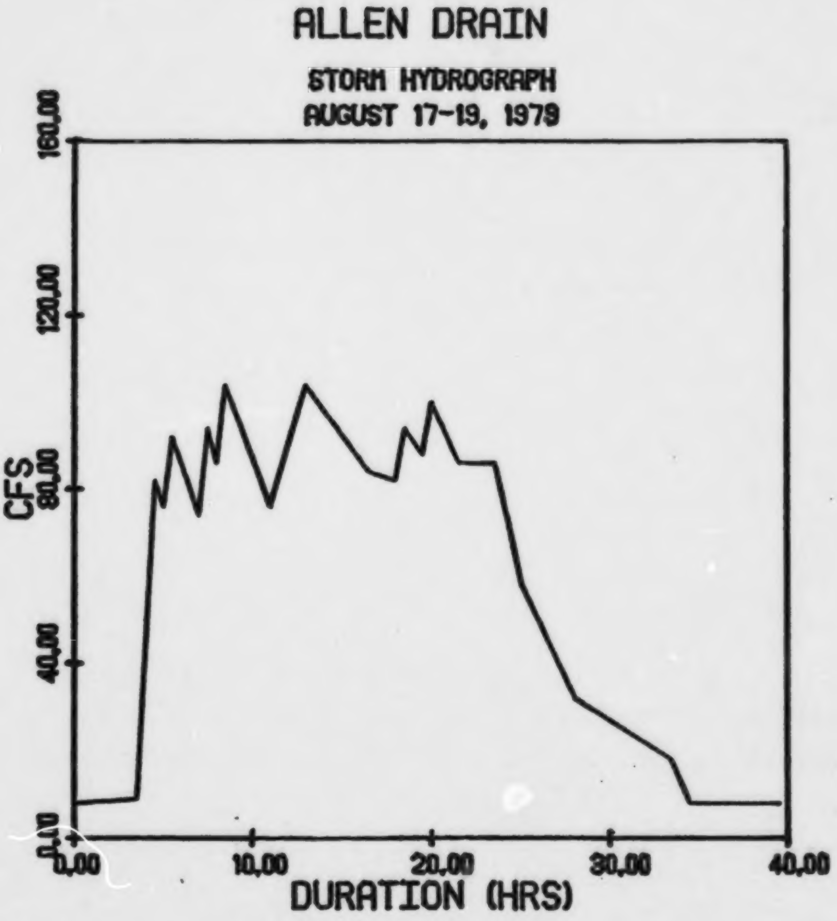

ALLEN DRAIN
STORM HYDROGRAPH
AUGUST 17-19, 1979
CFS
0.00
40.00
80.00
120.00
160.00
0.00
10.00
20.00
30.00
40.00
DURATION (HRS)

Figure VI-11

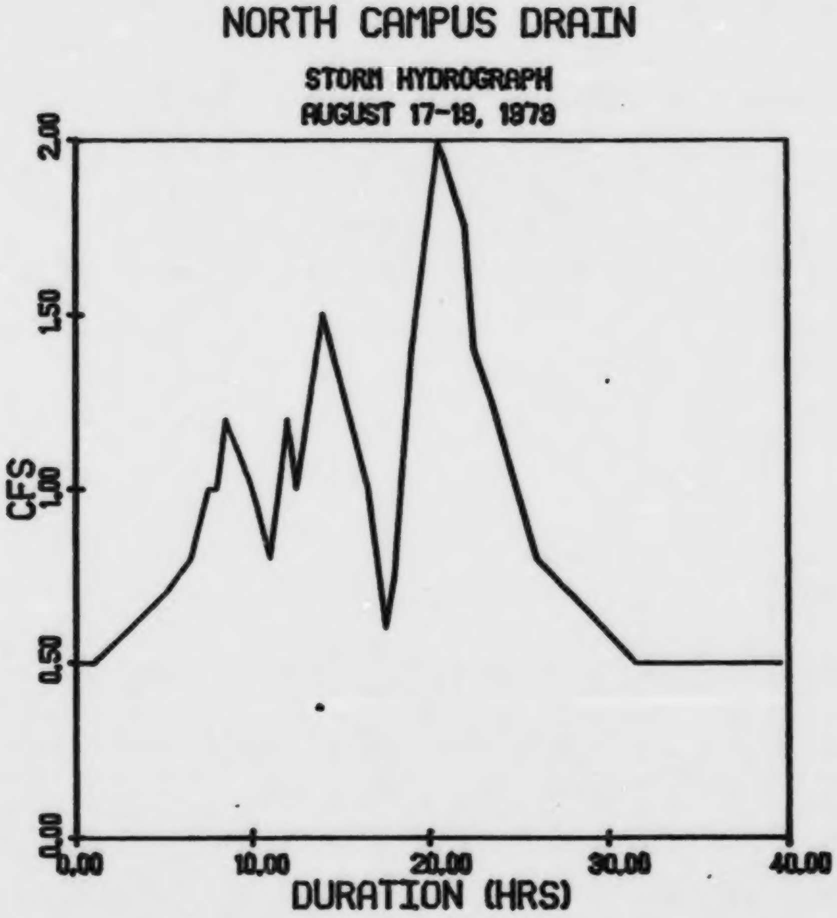

NORTH CAMPUS DRAIN
STORM HYDROGRAPH
AUGUST 17-19, 1979
CFS
0.00
0.50
1.00
1.50
2.00
0.00
10.00
20.00
30.00
40.00
DURATION (HRS)

Figure VI-12

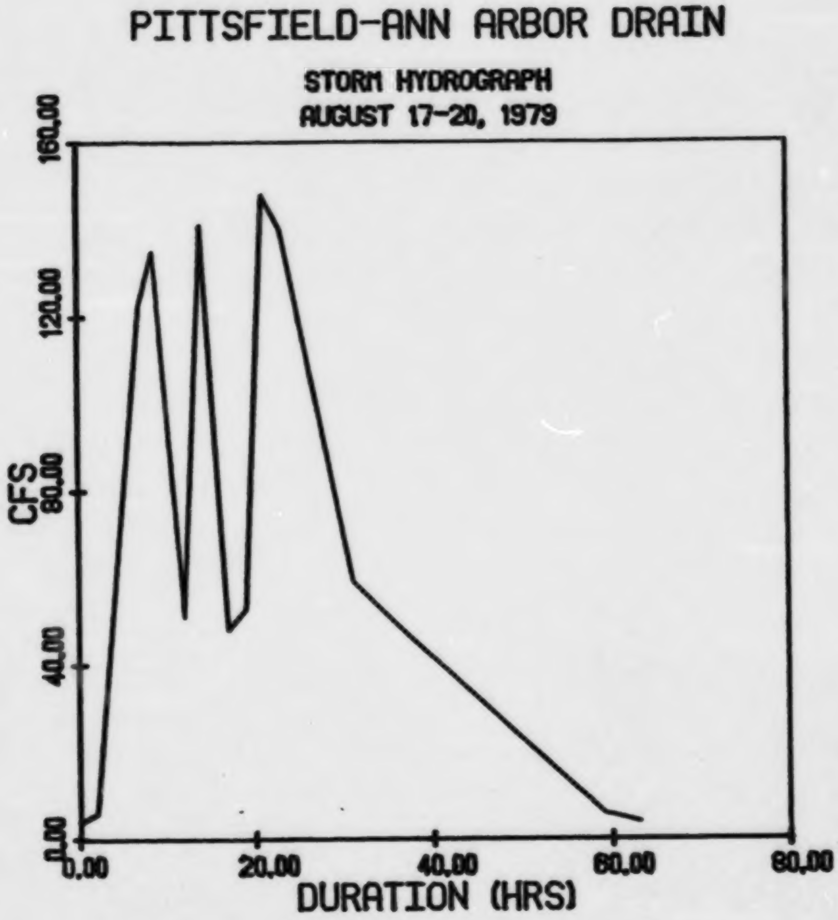

PITTSFIELD-ANN ARBOR DRAIN
STORM HYDROGRAPH
AUGUST 17-20, 1979
CFS
0.00
40.00
80.00
120.00
160.00
0.00
20.00
40.00
60.00
80.00
DURATION (HRS)

Figure VI-13

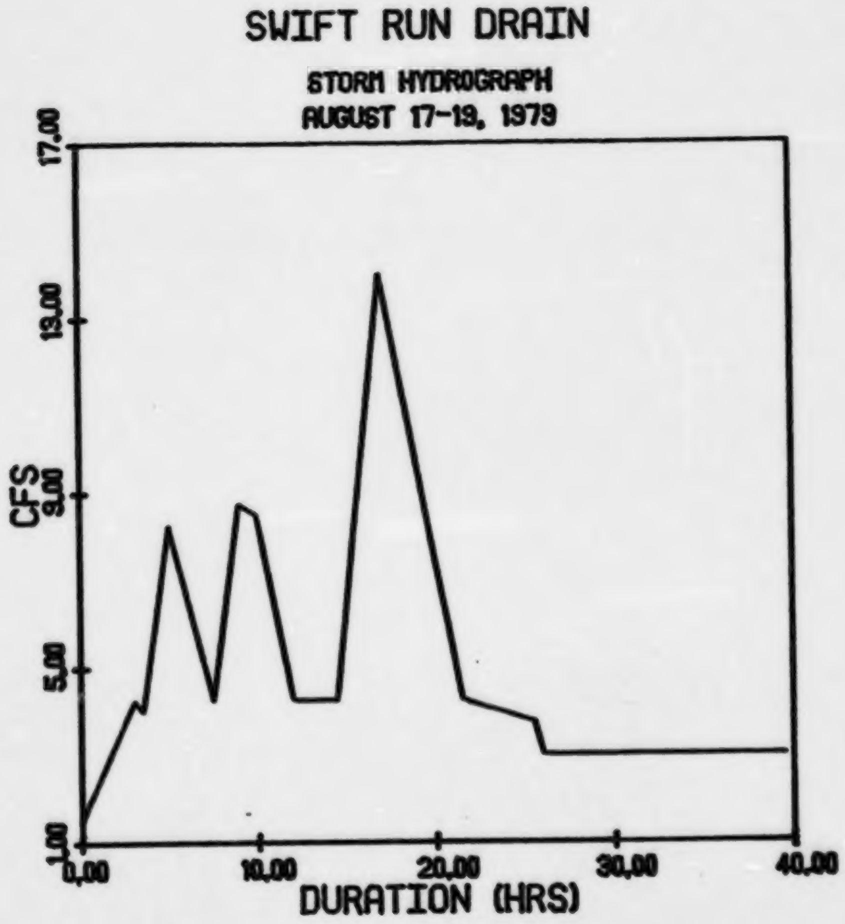

SWIFT RUN DRAIN
STORM HYDROGRAPH
AUGUST 17-19, 1979
CFS
17.00
13.00
9.00
5.00
1.00
0.00
10.00
20.00
30.00
40.00
DURATION (HRS)

Figure VI-14

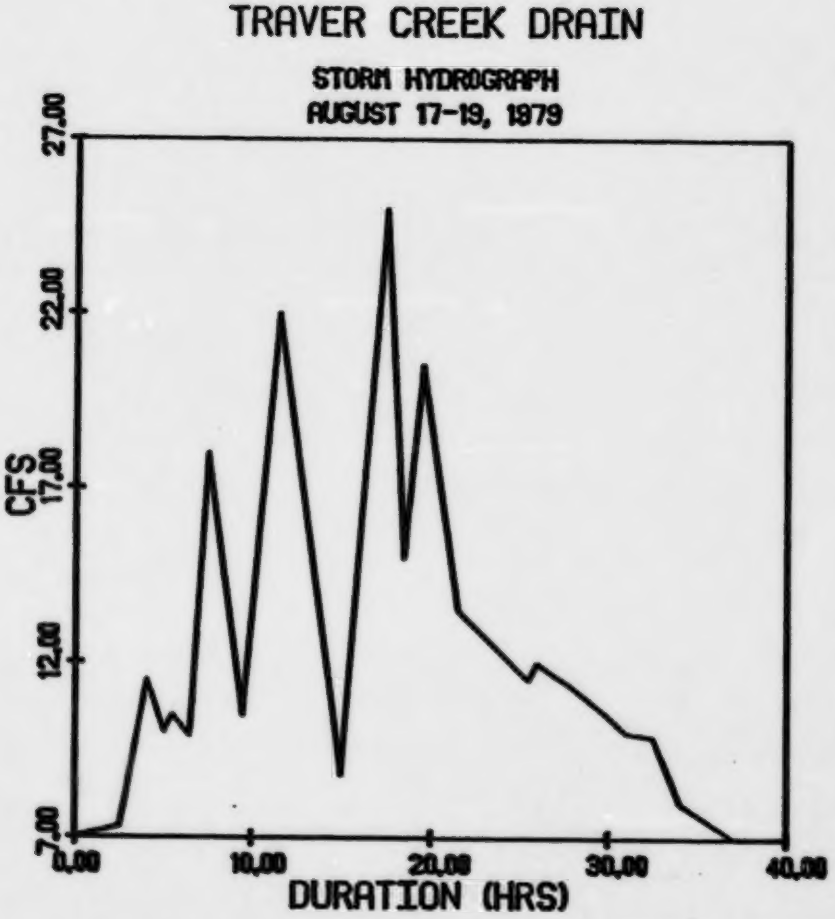

TRAVER CREEK DRAIN
STORM HYDROGRAPH
AUGUST 17-19, 1979
CFS
27.00
22.00
17.00
12.00
7.00
0.00
10.00
20.00
30.00
40.00
DURATION (HRS)

Figure VI-15

TABLE VI-20

Pollutant Loads
Ann Arbor, Michigan

August 17-20, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft.)	7,705	10,685	832	1,973	145
pH	(S.U.)	7.8	7.8	7.7	8.0	7.8
Total Dissolved Solids	(lbs.)	134,000	195,000	15,000	57,000	3,000
Total Suspended Solids	(lbs.)	52.600	142,000	7,000	9,880	570
Biological Oxygen Demand	(lbs.)	1,900	1,800	110	430	36
Total Kjeldahl Nitrogen	(lbs.)	430	800	47	120	8
Soluble Kjeldahl Nitrogen	(lbs.)	172	270	15	77	4
Nitrate	(lbs.)	200	156	13	77	2.7
Total Phosphorus	(lbs.)	138	60	6	4	1
Soluble Phosphorus	(lbs.)	<5.1	<11	<0.52	<1.5	<0.10

TABLE VI-20 (Continued)

Metal Loads
Ann Arbor, Michigan

August 17-20, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft.)	7,705	10,685	832	1,973	145
Iron	(lbs.)	920	3,310	180	200	16
Soluble Iron	(lbs.)	<16	28	2.2	3.1	0.28
Lead	(lbs.)	21	19	0.70	<4	0.10
Soluble Lead	(lbs.)	<0.48	<0.66	<0.05	<0.12	<0.01
Zinc	(lbs.)	96	95	7.7	18	1.1
Chromium	(lbs.)	7.1	9.7	1.6	0.87	0.11
Cadmium	(lbs.)	<0.18	<0.27	<0.02	0.06	0.002
Copper	(lbs.)	9.7	6.1	0.48	1.4	0.06
Nickel	(lbs.)	<1.0	2.8	0.23	0.35	<0.02

both characterized by having a large amount of roadways, discharged 0.006 pounds per acre and 0.003 pounds per acre of lead, respectively. Traver Creek, Swift Run, and North Campus Drains discharged 0.0009, 0.0002, and 0.00006 pounds of lead per acre. The dramatic difference in these loading levels show quite clearly the impacts of land use and cover on pollutant loads. The loading differences for total suspended solids and lead can also be observed for other constituents such as phosphorus, nitrogen and iron.

Table VI-21 presents the event mean concentrations (EMC) for selected representative parameters for all of the drains. As found in the snow melt data,when comparing EMC's of different parameters between the drain outlets, Allen and Pittsfield-Ann Arbor Drain do not always have the higher values of the five drains. There is no one drain that consistently exhibits the highest event mean concentration for each or even a majority of the parameters.

Composite samples of the Huron River from upstream (Argo Dam) and downstream stations (Geddes Dam) were collected over a ten day period. Samples were collected over this large length of time to ensure that sufficient volume of water had passed through the Geddes Pond to allow all inputs from the drains to be "flushed" through. Four volume changes were monitored during the sampling time. The event mean concentration of the data collected at these stations during the river survey are shown in Table VI-22.

The data shows very little change in water quality at Geddes during and after the runoff period. The higher event mean concentrations for some parameters found at Geddes dam when compared to values measured at Argo Dam illustrates the influence that the runoff waters do have on this reach of

TABLE VI-21

Event Mean Concentrations
Drain Outlets

August 17-27, 1979

Parameter	Unit	Allen Drain	Pittsfield Ann-Arbor	North Campus	Swift Run	Traver Creek
Flow	Cu. Ft.	7,705,000	10,685,000	145,000	832,000	1,970,000
TDS	mg/l	279	293	340	286	463
TSS	mg/l	109	213	63	135	80
TKN	mg/l	0.90	1.2	0.88	0.90	0.96
SKN	mg/l	0.36	0.40	0.44	0.29	0.63
TP	mg/l	0.29	0.09	0.11	0.12	0.03
SP	mg/l	<0.01	<0.02	<0.01	<0.01	<0.01
BOD	mg/l	4	3	4	2	3.5
T-Fe	mg/l	1.9	5.0	1.8	3.5	1.6
S-Fe	mg/l	<0.03	0.04	0.03	0.04	0.03
T-Pb	mg/l	0.04	0.03	0.01	0.01	<0.03
S-Pb	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001
NO_3-N	mg/l	0.42	0.23	0.30	0.25	0.62

TABLE VI-22

Event Mean Concentrations
Argo Dam/Geddes Dam

August 17-27, 1979

Parameter	Argo Dam (mg/l)	Geddes Dam (mg/l)
TSS	7.4	14.1
TDS	350	343
BOD	1.7	2.0
NO_3-N	0.05	0.09
TKN	0.60	0.73
SKN	0.46	0.51
TP	0.02	0.06
SP	0.009	0.01
T-Fe	0.22	0.42
S-Fe	0.007	0.007
T-Pb	0.002	0.002
S-Pb	<0.001	<0.001
T-Zn	0.11	0.10
T-Cr	0.01	0.01
T-Cd	0.0001	0.0001
T-Cu	0.001	0.002
T-Ni	<0.001	<0.001

the river. Increases in total suspended solids, nutrients and total iron can be seen. The particle size data (Table VI-23,24) shows a slight shift in distribution reflecting the settling out of some of the larger particles in the basin.

Summaries of the pollutants entering and leaving the impoundment are presented in Tables VI-25. These summary tables are based on total loadings entering (from upstream sources and drain outlets) and leaving the study area during the runoff period. The loadings presented include both baseflow conditions and loadings from the rainfall period. Individual parameter values for each composite are presented in the Separate Data Report. Like the snow melt event, removal efficiencies of over fifty percent are seen for total suspended solids, total iron, lead, zinc, cadmium, copper, and nickel. Removal of nutrients does not occur.

DISCUSSION - IMPACTS DURING MONITORED EVENTS

The water quality data from the river and drain outlet surveys performed during this study, summarized in Tables VI-17 and VI-25, show the total input of various pollutants to the pond from the five storm drains which were monitored. The input to this reach of river from upstream areas and the discharge levels at Geddes pond are shown for a period of several days. This mass balance approach to summarizing inputs and outputs was used to provide an indication of the conditions occurring in this reach of river. The balances cover several days in order to account for the time of travel through the impoundment area.

TABLE VI-23

PARTICLE SIZE DISTRIBUTION
Drain Stations

August, 1979

	MICRON SIZE	Composite 1		Composite 2		Composite 3		Composite 4	
		Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.	Conc. mg/l	Load lb.
Argo Drain									
	>60	84+	11,000	10	2,450	3	230	<10*	<250
	10-60			99	24,300	6	470		
	4-10	38	5,000	27	6,600	6	470		
	<4	1	130	14	3,400	1	78		
Pittsfield - Ann Arbor Drain									
	>60	10	1,500	5	1,900	6	650	5	100
	10-60	149	23,000	120	46,000	22	2,400	9	180
	4-10	58	8,900	79	30,300	19	2,100	10	200
	<4	24	3,700	51	19,600	14	1,500	3	60
Swift Run Drain									
	>60	3	24	---	---	4	40	4	60
	10-60	180	1,400	137	2,900	16	150	2	30
	4-10	62	500	45	950	13	120	3	40
	<4	27	220	32	670	11	100	3	40
Traver Creek Drain									
	>60	6	110	6	250	<10*	<300	<10*	<320
	10-60	39	740	146	6,200				
	4-10	7	130	35	1,500				
	<4	4	75	16	680				
North Campus Drain									
	>60	---	---	59	210	33+	60	8	20
	10-60	---	---	18	60			15	30
	4-10	---	---	15+	50	11	20	5	10
	<4	---	---			4	7	4	9

+ Includes both groups.
* TSS ≤ 10 mg/l.

TABLE VI-24

PARTICLE SIZE DISTRIBUTION

LOCATION: Huron River Stations   DATE: August 1979

	MICRON SIZE	Composite 1 Conc. mg/l	Composite 1 Load lb.	Composite 2 Conc. mg/l	Composite 2 Load lb.
Argo Dam					
	>60	3	1,600		
	10-60	10	5,400		
	4-10	5	2,700		
	<4	4	2,200		
Geddes Dam					
	>60	3	3,400	2	1,600
	10-60	3	3,400	7	5,800
	4-10	7	8,800	6	4,900
	<4	5	6,300	5	4,100

TABLE VI-25

POLLUTANTS ENTERING AND DISCHARGED FROM GEDDES POND, HURON RIVER

August 17-27, 1979

	Volume Cu ft.	Total Dissolved Solids lbs.	Total Suspended Solids lbs.	Biological Oxygen Demand lbs.	Nitrate lbs.	Total Kjeldahl Nitrogen lbs.	Soluble Kjeldahl Nitrogen lbs.	Total Phosphorus lbs.	Soluble Phosphorus lbs.
Upstream River Water (Argo Dam)	119×10^6	2.6×10^6	55,000	12,500	390	4,400	3,400	170	<70
Storm Drains (5)	21.3×10^6	404,000	212,000	4,300	450	1,400	500	210	18
Total	140×10^6	3.0×10^6	267,000	16,800	840	5,800	3,900	380	<88
Discharged From Geddes Pond	140×10^6	3.0×10^6	123,000	17,500	750	6,400	4,500	490	<90
Pollutant Remaining in Geddes Pond		0	144,000	(-700)	90	(-600)	(-600)	(-90)	2
Percent of Drain Input Remaining in Geddes Pond		x	68	(-16)	20	(-43)	(-120)	(-43)	x

NOTE: Loads for drains represent runoff amounts during the event.
Loads for dams are for 7-day period during and after the event.

x = 0±10%

TABLE VI-25 (Continued)

METALS ENTERING AND DISCHARGED FROM GEDDES POND, HURON RIVER

August 17-27, 1979

	Volume Cu. ft.	Total Iron lbs.	Soluble Iron lbs.	Total Lead lbs.	Soluble Lead lbs.	Total Zinc lbs.	Total Chromium lbs.	Total Cadmium lbs.	Total Copper lbs.	Total Nickel lbs.
Upstream River Water (Argo Dam)	119×10^6	1,660	49	<17	<7.4	790	98	<0.9	<8.5	<7.4
Storm Drains (5)	21.3×10^6	4,620	50	45	1.3	220	20	0.5	18	4.4
Total	140×10^6	6,280	99	<62	<8.7	1,010	118	<1.4	<26	<11.8
Discharged From Geddes Pond	140×10^6	3,650	58	21	<8.7	900	120	<0.9	13	<9
Pollutant in Geddes Pond (Mass Balance)		2,630	41	<41	0	110	(-2)	<0.5	<13	<3
Percent of Drain Input Remaining		57	82	<91	x	50	x	<100	<72	<68

NOTE: Loads for drains represent runoff amounts during the event.
Loads for dams are for 7-day period during and after the event.

x = 0±10%

It is evident from inspecting the data that large quantities of suspended solids are discharged from the storm drains and are retained within the Geddes pond area. Both the snow melt and summer surveys support this observation. The data indicates that 80-90% of the incoming solids loadings are retained in the pond. Heavy metals are also being held within the impoundment. Lead and iron, both measured in reasonably high levels, were held within the impoundment in high percentages (60-90%). During the snow melt period, phosphorus also was retained within the pond area, while it appears that this was not the case during the summer period using the net mass balance approach. Total Kjeldahl nitrogen concentrations increased at Geddes Dam following the snow melt period while there was little change in overall concentration during or following the summer event.

Table VI-26 shows the projected concentration in the river of various chemical parameters during the actual runoff period. These values are projected by combining the upstream flow and concentration values at Argo Dam with the drain flow and discharge loads during the duration of the runoff. As can be seen elevated concentrations of suspended solids, phosphorus and heavy metals occur in the river during the runoff period. Oxygen demanding materials are generally low in concentration and thus do not cause severe oxygen depression in the river.

Numerical water quality standards have been specifically established for lead (50 ug/l) and cadmium (10 ug/l) while suspended solids and nutrients have no numerical standards for comparison. General guidelines (Appendix II) for suspended solids and nutrients (TSS - 25 mg/l, TKN - 0.8 mg/l, T-P >0.05-0.10) are used to suggest eutrophication or

TABLE VI-26

Projected Pollutant Concentrations In The Huron River - Snow Melt, Rain Events

Snow Melt, 1979 Parameter	River Background (mg/l)	Projected River Levels With Storm Load (mg/l)	Geddes Dam (mg/l)
Suspended Solids	8	65	9
Total Phosphorus	.02	.12	.04
Total Kjeldahl Nitrogen	.89	1.6	1.0
Biochemical Oxygen Demand	2	9	3
Lead	.001	0.1	.01
Iron	0.13	1.6	.24
Cadmium	.0001	.003	.0001
Zinc	.009	.15	.03
Copper	.002	.03	.004
Rain Event, 1979			
Suspended Solids	7	61	14
Total Phosphorus	.02	.07	.06
Total Kjeldahl Nitrogen	0.6	.76	.73
Biochemical Oxygen Demand	1.7	2.2	2.0
Lead	.002	.012	.002
Iron	0.02	1.4	0.4
Cadmium	.0001	.0002	.0001
Zinc	.01	.13	.01
Copper	.001	.006	.002

impairment of aquatic life may potentially exist. Comparison of the data in Table VI-26 with the standards and guidelines shows that the lead standard is exceeded during the snow melt. Suspended solids levels are twice the guideline and phosphorus levels increase substantially over the background level. The increases in these constituents occur only in the river during runoff periods which tend to be of short duration. Thus the exceedance of the standards and/or guidelines is a temporary situation. Given the fact that the lead standard is based on a continuous exposure basis and the guidelines are based on long term biological impacts (i.e. eutrophication), these short term levels of solids, nutrients and metals do not appear to result in immediate or acute water quality problems in the river during the runoff period. Suspended solids discharges result in very turbid water and are an aesthetic nuisance problem following storm events.

The solids, phosphorus, and metals levels decrease following the storm events due to sedimentation in the impoundment. This results in the water quality of the river at the Geddes dam overflow being within the standards and guidelines for the various chemical constitutents. Thus, it appears that present stormwater discharges do not result in severe water quality degradation in the river and any immediate impacts downstream which could occur are attentuated by sedimentation in the impoundment. This results in protection for downstream river areas through the trapping of pollutants within the Ann Arbor reach of the river. However, the retention of these pollutants within the impoundment area raises the question of long term impacts due the accumulation of materials in the park area. The question of long term impacts will be discussed further in relation to the annual loads entering the river.

The water quality survey performed by Semcog as part of the 208 program showed similar findings to these surveys. During the 208 water quality survey the river was monitored during and after a storm. The general findings were that the water quality conditions at Geddes dam did not change significantly, although slight increases in lead, iron, and ammonia nitrogen were noted. Only one storm drain outlet (Allen), was monitored during this survey so a mass balance cannot be performed for comparison with this study. The general result, however, was similar showing no apparent severe immediate water quality problems.

The one exception to this general evaluation is the case of fecal coliform. Grab samples of the drains taken during this study, the 208 study, and other surveys have shown that fecal coliform levels in the range of 10^3 - 10^5 can be excepted in the runoff waters. These discharges will result in fecal coliform levels above the standard for total body contact of 200 cfu/100 ml. established by the State of Michigan. The levels will be mixed in the large pond volume and with incoming water. Considering mixing coupled with natural die-off it can be estimated that the standard will be violated at various locations for 1-5 days after the storm depending on the size and duration of the event. Thus while water quality conditions in general are not severely degraded immediately during a storm event, water quality standards for total body contact can be expected to be exceeded at certain times, resulting in loss of potential recreational use of this area. The water quality standard for fecal coliform is not actually violated during the storm events due to the wording of the standard. The 200 cfu/100 ml limit is waived if the source of coliform is a non-point source (see standards section).

EVENT/ANNUAL LOADS IN THE HURON RIVER

As stated in the previous discussion, short term impacts of storm water discharge on this stretch of the Huron River did not appear to be severe for the monitored events. Long term impacts, however, require consideration due to the sedimentation of materials in the Geddes impoundment. The size of this impoundment in relationship to the river flow (54×10^6 Cu. Ft., median river flow - 300 cfs) results in a body of water with characteristics inbetween a river and a lake. In order to assess the impact of stormwater runoff under typical conditions, the data collected during this study was used to project drain discharge conditions and river conditions for various size rainfall events and on an annual loading basis.

The method utilized combined data on background water quality conditions in the river from STORET, river flow data from the USGS, and the event and annual non-point source loading data presented in Chapter V. This data was utilized to project water quality conditions during storm events for various size storms and river flow conditions. River flows representing the median flow, mean flow, and dry flow (95% of flow values greater than), 300 cfs, 420 cfs, and 85 cfs respectively, were used in this evaluation. Rain event sizes of 0.3 inches (mean) and 0.9 inches (95% Less than) were selected for the evalution of projected concentrations in the river using the established event mean concentrations. Annual loadings from Chapter V, historical data above and below this reach of river, and the monitoring data presented earlier were used to project the quantity of pollutants being deposited in the sediments.

Table VI-27 shows the projected concentrations of various contaminants which can be expected during runoff periods. The projections are based on a 24-hour average runoff duration with all of the storm runoff being mixed with the incoming river flow. Table VI-28 shows the projected annual loadings of five parameters (TSS, T-P, TKN, Pb, Fe) to the river from the drainage system and the annual load of material being retained in the bottom sediments.

IMMEDIATE IMPACTS

The projected concentrations in Table VI-27 provides a basis for comparing river water quality conditions with the State of Michigan water quality standards and guidelines. In general for those few parameters for which actual numerical standards are set (Lead - 50 ug/l, Cadmium - 10 ug/l, dissolved oxygen - 5.0 mg/l) the standards are not violated for most rainfall event - river flow combinations. As stated earlier fecal coliform levels will exceed 200 cfu/100 ml but this standard does not apply if non-point sources are the cause of elevated levels. The guideline levels are exceeded during the runoff period but these guidelines are generally applied for long term continuous exposure levels rather than the short duration type conditions being considered here. Therefore, the general conclusion reached for the monitored events, namely, no immediate acute water quality problems occur due to the non-point source loadings, appears to be the case for typical rainfall conditions under the current loading conditions.

TABLE VI-27

Projected Concentrations During Runoff Events
Huron River Argo - Geddes Reach

	Background Concentration mg/l	Projected River Concentration River Flow 85 cfs mg/l	River Flow 300 cfs mg/l	River Flow 420 cfs mg/l
Mean Event 0.3 inches rainfall				
Suspended Solids	7	51	24	19
Total Phosphorus	.04	.08	.05	.05
Total Kjeldahl Nitrogen	.77	.90	.81	.80
Total Lead	.001	.02	.008	.006
Total Iron	0.18	1.3	0.6	0.5
0.9 inch rainfall				
Suspended Solids	7	85	47	38
Total Phosphorus	.04	.11	.07	.07
Total Kjeldahl Nitrogen	.77	1.0	0.9	.85
Total Lead	.001	.036	.018	.016
Total Iron	.18	2.2	1.1	0.9

TABLE VI-28

ANNUAL POLLUTANTS
Geddes Impoundment - Huron River

	Total Pounds* Annual	Estimated Pounds Retained Annual
Suspended Solids	3,000,000	2,400,000
Total Phosphorus	3,300	1,000
Total Kjeldahl Nitrogen	25,000	2,500
Total Lead	1,300	1,000
Total Iron	74,000	44,000

* Storm drains

LONG TERM IMPACTS

As shown in Table VI-28, the Geddes impoundment receives large quantities of suspended solids, nutrients, and metals from the storm drainage system. These pollutants are discharged during runoff periods with a major fraction of the pollutant load remaining in the impoundment. The deposition of these materials creates the potential for long term impacts in the water quality of the pond and downstream waters.

Evaluation of the loading data indicates that the long term impacts of the storm drain discharges to the river which are of most concern are the nutrient additions accelerating the eutrophication process and the accumulation of sediment in the pond which concentrates metals and destroys the benthic environment. Early studies on the river by Borchardt and subsequent studies by other investigators have shown that nutrient levels increase in the river as it flows towards Lake Erie. The section of river above the Geddes dam station receives virtually no point source discharges of consequence. Thus, increases in nutrients are attributable to non-point sources. The increases in phosphorus and nitrogen in the Geddes pond area has been documented by past dry weather surveys and by recent wet weather surveys. Comparison of samples at Argo dam and Geddes dam during this study and during earlier studies shows increases in both total phosphorus and total Kjeldahl nitrogen. Past data would indicate that increases in nutrients occur during dry weather flow conditions. The very few biological samples which have been collected in Geddes Pond indicate algal blooms occasionally occur in the pond and increased levels of chlorophyll have been measured. It would appear that increased nutrient levels during the warm months can be attributed to the uptake and utilization of nutrients in the pond.

The data collected during this study indicates phosphorus is settled in the colder periods, while no net change in phosphorus was detected during the August survey. It is difficult to conclude that phosphorus is not settling in the summer time particularly given the additional data which shows that most of the phosphorus discharged is insoluble. Instead, it would appear that phosphorus is being utilized by the biological community, recycled from accumulated materials and is actually being discharged at higher levels than the incoming levels (Argo Dam) during dry periods. This would indicate that the phosphorus discharged by the drains enters the river, is utilized by biological community and is then discharged over a long period of time.

The phosphorus levels at Argo Dam ranged from 0.01 to 0.04 mg/l during current surveys and was in the range of 0.01 to 0.05 mg/l in previous studies. Phosphorus levels measured at Geddes Dam ranged from 0.01 to 0.10 mg/l during the current work and historical data over the past ten years shows a range 0.03-0.10 mg/l. This data shows a trend of generally increasing phosphorus levels. The increase in phosphorus can contribute to the development of eutrophic conditions which can result in a general degradation of water quality. Currently, moderate algal blooms have been noted in the impoundment but severe conditions have not apparently occurred. However, continued increases in phosphorus levels through continued discharge and increased discharge from new developed areas will undoubtedly have significant negative impacts on water quality conditions.

In addition to nutrients, large amounts of suspended solids are discharged from the storm drains (3,000,000 pounds annually). Heavy metals, particularly lead and iron, are associated with these solids materials and are deposited in the bottom of the pond. The data shows quite clearly that most of the solids discharged by the drains settle in the pond. In addition, data from Argo dam shows that very little settleable material enters the pond from upstream areas. The upstream ponds buffer Geddes Pond just as Geddes Pond buffers downstream areas. The buildings of silt in Geddes Pond is directly attributable to the storm drains in this reach.

The deposition of solids can affect the environment of bottom dwelling organisms. A brief benthic survey by the School of Public Health found that the bottom of Geddes Pond was characterized as soft and silty material containing a considerable amount of organic matter. Organisms found within the impoundment included oligocheates and chironomids. Above the City, the study found a more diverse population of macroinvertebrates. This brief study is supported by current visual observations which indicates soft silty material at several locations in the pond. This was observed during placement of sediment chambers in the pond. Background information supported by the surveys conducted during this study shows quite clearly that the storm drains are contributing the major portion of silt buildup in the pond.

In addition to affecting the benthic environment directly, siltation and buildup of solids will affect fish populations as well. The fish are affected both through the general destruction of the environment and also through the loss of food when benthic organisms cannot survive. A study of fish species in 1972 showed carp was the most abundant species in the pond. Because of the dominance by carp the river was chemically treated to remove the carp. The river was restocked with game fish. A follow-up survey indicated that some game fish were surviving but carp were once again becoming the predominant species. The only species which appear to be doing well, naturally, are the carp, bluegill and croppie. Thus, it would appear that water quality conditions, while capable of supporting some game fish, and not in violation of standards, are not sufficient to support reproduction and survival.

The buildup of sediment in the pond is also accompanied by metals as shown from the data collected. The discharges of lead and iron from the storm drains are quite high. Lead is mostly in the insoluble form and thus is captured in the sediment. It can be expected that buildup of lead will continue as long as discharges continue in this reach.

During the two water quality surveys on the river, over 240 pounds of lead were discharged to the river. The projections show approximately 1,300 pounds per year of lead are discharged into this section of river and much of it is retained in the sediments. Two long term processes appear to be taking place due to the discharge of these high levels. The sediments will continue to increase in lead levels and will undoubtedly enter the food chain to some degree. This will have long term implications should it be desired to continue to attempt to improve the fish habitat in the pond for recreational purposes. While under current conditions, the lead will remain in the insoluble form. However, a shift in hardness and pH for any reason could result in the release of lead from the sediments which could create a severe water quality problem. In addition to the accumulation of undesireable amounts of lead and other metals in the sediment, levels of lead in the water column also show a general increase. Levels of lead at Geddes dam during the snow melt increased dramatically to 0.026 mg/l. Also data during dry weather and wet weather periods indicates a general increase in lead levels from Argo to Geddes dam (from <0.001 to 0.001-.026 mg/l respectively). This increase is due to the discharge and accumulation of lead in this reach of the river. The increase in overall lead levels can be expected to continue as long as the urban runoff continues to discharge the heavy metal materials.

It is quite apparent that the urban storm drains can have a major impact on water quality in the Geddes Pond reach of the Huron River. The 208 program identified this area of the Huron River as a segment being impacted by urban runoff and requiring further attention and ultimately control. The findings of this study support the 208 evalution and indicate even more clearly the role of urban runoff in the area. Current general water quality conditions in the Geddes Pond reach could be classified as fair with no immediate severe water quality problems, but overall deterioration of water quality does occur as the river flows through the urban area. It can be expected that water quality in the river will deteriorate further if increasing loadings to the river continue. New development will result in increased loads to this stretch of river unless management controls are required. The current loads from urban runoff are generated from approximately 10,000 acres of highly developed land. There exists an additional 9,000 acres which can be developed in coming years and have direct discharge to Geddes Pond. Thus, if no controls are utilized a doubling of the current pollutant loads can be expected. This will undoubtedly result in deterioration of water quality and impairment of the recreational facilities which have been developed along the river.

In assessing the water quality impacts of urban runoff in the Huron River, the Semcog 208 program compared point and non-point source loading for various areas. In comparing the relative loads between the urban runoff from Ann Arbor and the Ann Arbor Wastewater Treatment Plant, the 208 report showed that point sources were still the largest contributor of nutrients and solids (1977). Upgrading of the wastewater plant will reduce the point source loadings. Table VI-29 shows a comparison between the total drain loadings and the Ann Arbor Plant (located below Geddes Dam) for the two events monitored.

A comparison of the annual loadings (in pounds) from the five storm drains and the wastewater plant is shown below:

	Annual Load Storm Drains	Annual Load Treatment Plant
Suspended Solids	3,000,000	610,000
Phosphorus	3,300	60,000
Kjeldahl Nitrogen	25,000	300,000
Lead	1,300	550
Iron	74,000	62,000

As can be seen in these tables, the urban runoff represents a large load of suspended solids in comparison to the treatment plant. Similar levels of lead and iron are discharged from each source on an annual basis while during a given rain event the runoff water will contribute a much larger immediate load. The point source is the major contributor of nutrients even with tertiary treatment on an

TABLE VI 29

LOADINGS OF SELECTED POLLUTANTS
Snow Melt Event - Comparison of Non-Point and Point Sources
Ann Arbor, Washtenaw County, Michigan

February 23, 1979

	Total Five Drains	Ann Arbor Treatment Plant Discharge lbs/day	Equivalent Days of Treatment Plant Discharge Equal to 24 hour Runoff Event**
TSS	114,400	1,670	68
BOD_5	15,500	1,000	15.5
NO_3N	1,181	1,670	0.7
TKN	2,000	830	2.4
T-P	242	230	1.05
T-Fe	2,880	170	17
T-Pb	191	1.5	127
TSS	212,000	1,670	127
BOD_5	4,276	1,000	4.3
NO_3N	448	1,670	0.3
TKN	1,405	830	1.7
T-P	209	230	0.9
T-Fe	4,626	170	27
T-Pb	45	1.5	30

NOTE: Drain Loadings are based on flow proportional composite samples and represent approximately 24 hours of discharge for this event (i.e. flow from melt occurred for approximately 24 hours before returning to base flow conditions).

* Assume treatment plant flow of 20 MGD and effluent meeting tertiary plant standards.

** Number of days of treatment plant flow which would discharge the equivalent load measured during the 24 hour discharge from the storm drains.

annual basis. This comparison shows the importance of urban runoff in overall water quality management planning. It is quite clear that with the improvement in point source treatment, urban runoff will be a major contributor of pollutants entering the river.

SUMMARY OF URBAN RUNOFF PROBLEM

The NURP project team has developed three definitions of the urban runoff "problem". The three definitions are:

1. Problems Resulting from Denial or Impairment of Beneficial Use.
2. Violation of Water Quality Standards.
3. Problems Resulting from Local Concern.

Violation of water quality standards has been addressed directly in the discussion and the results of this study show that urban runoff in the study area does not cause violation of the standards. The one standard for fecal coliform which is exceeded, is not a violation because the standard specifically waives the violation if the source is due to storm water runoff.

The other two "problems", impairment of beneficial use and local concern are both more subjective problems to evaluate and both do apply to the Ann Arbor area. Considerable amounts of time and money have been spent to develop the Geddes impoundment area and upstream sections of the river into recreational areas. An extensive park system, as outlined earlier, has been established and thousands of local residents use the facilities. In addition to general park usage, sailing and canoeing are major activities in Geddes "Lake". There is also a tremendous public interest in the Huron River including a major event Huron River Day, which occurs each summer. Local officials and citizen groups have continually heightened awareness in the general public of the importance of protecting this valuable water resource. It is in this context that the runoff ordinances and BMP's have been established with wide ranging support from the general public.

The current discharges from the storm drains are not generally denying the beneficial uses for the river. However, there is impairment of the use of the river immediately following major storm events. High turbidity levels and floating debris cause nuisance conditions which remain until sedimentation occurs. This reduces the public use of the river for boating and other activities. The major impairment which appears to be occurring at this time is the inability of this section of river to support a fishery. As stated earlier, the river was stocked but does not appear to be capable of supporting the more desireable species of fish without continued stocking programs. While urban runoff may not be the entire reason for this impairment, the heavy loads of solids and metals contributed to the river must be considered an important factor. The major concern both from a local perspective and beneficial use criteria is the long range impact the buildup of these materials will have on the water quality in the reach of river. Accumulation of nutrients, metals, and solids, in addition to continued development activities with increased urban runoff loads, presents a greater potential for water quality problems in the future. Over 30% of the land draining to Geddes Pond is still in an undeveloped state, lying in the headwater areas of the drainage system. In addition large areas upstream of the Geddes pond area also will eventually be developed. Allowing these areas to develop without controls would clearly lead to decreasing water quality in this reach of river. Implementation of available water quality controls in conjunction with flood controls would appear to be feasible and the logical approach to use. Given the current available controls (retention ponds, detention ponds, etc.) it would appear that water quality in the river would probably not improve dramatically but these controls would provide protection against any further degradation in water quality.

EFFECTIVENESS OF CURRENT INPLACE CONTROLS

The Ann Arbor area has been implementing various types of urban runoff strategies for the past several years. The primary focus of these controls has been on reducing flooding problems due to newly developing areas. The BMP's monitored during this study were installed as part of the overall approach to resolving flooding problems. In the past five years the consideration of water quality control in addition to flood control became an important issue as shown in the runoff ordinanace discussion. Flood control continues to be the major driving force behind the implementation of various control methodologies but as can be seen from this work, water quality controls can be blended with the flood control strategies to gain overall control of urban runoff waters.

Local implementation of runoff control has resulted in approximately 30% of the developed urban area receiving some type of control with the major areas being the Pittsfield Ann Arbor drain series of retention basins and the retention basins on the townhouse developments in the North Campus Drain. In addition the preservation of the Swift Run Wetland provides an important control for the landfill area. The Traver Creek basin currently receives runoff water primarily from undeveloped areas but the basin will serve an important function as the area develops. Considering only the current controls and the developed areas, estimates of the quantity of pollutants being removed have been made and are shown below:

	Current Total Annual Loading to Geddes	Pollutants Retained In Controls Pounds
Suspended Solids	3,000,000	350,000
Total Phosphorus	3,300	600
Lead	1,300	110

As can be seen significant removal of pollutants is being achieved in the controls in the newly developed areas. Considering the controls were primarily developed for flood relief and thus did not attempt to enhance pollutant removal, the removal levels are reasonably good. With improved knowledge in the design of basins or the use of other control strategies, better control should be gained over developing areas in the future.

REFERENCES

1. Environmental Assessment for Wastewater Management in the Ann Arbor - Ypsilanti Areas of the Huron River Valley, Washtenaw County, Michigan, Environmental Control Technology Corporation, Ann Arbor, Michigan, 1976.

2. Southeast Michigan Council of Governments, Water Quality in Southeast Michigan: The Huron River Basin; Detroit, Michigan, 1978.

APPENDIX I

App - I

APPENDIX I. QUALITY ASSURANCE

CHEMISTRY QUALITY ASSURANCE PROGRAM

The purpose of this section is to present an overview of the laboratory quality assurance program and a summary of the precision and accuracy data generated relative to the Nationwide Urban Runoff Program, Washtenaw County, Michigan. The results of the most recent US EPA Performance Evaluation analyses are also provided. The Q.C. data and operations documentation embodied in this report demonstrate that the data values being generated for this project are scientifically valid, defensible, and of known precision and accuracy.

The quality assurance program that is adhered to for all samples analyzed in the ENCOTEC chemistry laboratory incorporates two primary elements.

I. The control of laboratory operations
II. The control of measurements

I. The control of laboratory operations:

The laboratory QA program seeks to eliminate (determinate) errors through the control and standardization of the laboratory practices, equipment, and analytical procedures.

These control measures include:

A. The frequency of maintenance and calibration of all instruments.

B. The purity of all chemicals and reagents.

C. The quality of glassware used by the analysts.

D. The uniformity of methods.

E. The training received by the laboratory personnel.

F. The routine comparison of instrumental response with historical performance.

G. Formatted sample receipt forms and uniform sample labeling for internal tracking of samples.

H. Formated data sheets with clear documentation of all analytical variables.

These control measures keep an analytical method in control by standardizing it on a constant basis. For the same reason they also facilitate the trouble shooting of a method that is judged out of control. The exclusive use of EPA approved methods provides a common data base for comparison purposes. All methods cited in this report refer to US EPA Methods for Chemical Analyses of Water and Wastes, March 1974.

II. The control of measurements:

The control of measurements provides the continuous assurance that measurements and data values from the laboraotry are generated when the analytical system, whether it be wet chemical, instrumental, or gravimetric, is operating within control. To do this precision and accuracy limits for each method are developed yearly and tabulated and/or graphed. These limits are then checked each time QA samples are analyzed to assure that the analysis is always conducted in a controlled manner.

On a day to day basis, the laboratory QA program incorporates the following procedures into routine laboratory activity:

1. A series of calibration standards are analyzed with each batch of samples, a minimum of once per day.
2. Method blanks are included with each batch of samples analyzed, a minimum of once per day.
3. Sample duplicates are analyzed at a 10% frequency.
4. US EPA blind quality control check samples are analyzed at a 5% frequency, where applicable.
5. Sample spikes for the metal and organic parameters are analyzed at a 5% frequency.

NOTE: In accordance with US EPA methodologies, all metals samples analyzed by the furnace technique arse checked for matrix interferences by the method standard additions.

The QC data generated from these procedures for the Washtenaw County Drain project was initially checked by a Group Leader. The calculated values for standards, blanks and ampules, and the recoveries of sample spikes were reviewed. The linearity of the calibration curves was also checked. If all data was judged acceptable by the Group Leader, it is compiled and the raw data transmitted to the QC Coordinator.

The QC Coordinator then records the duplicate sample data on Precision Quality Control data sheets. The percent Relative Standard Deviation (% RSD) and absolute difference (R) of duplicate sets are then computed.

The control limits for precision have been established from actual laboratory performance data. In accordance with US EPA QC recommendations, these limits have been computed for each analysis by averaging the absolute differences (R - values) of sample duplicates, within a specific concentration range. This data has been gathered over a period of time, typically three months or more. The average value (R) is multiplied by the Shewhart factor, D_4, to set the upper confidence limit (UCL) for the absolute difference of duplicate values. An upper warning limit (UWL) is established by the formula $UWL = 2/3\ (D_4\ R - R) + R$.

The QC Coordinator now uses the UCL and UWL, generated from actual ENCOTEC data as acceptance/rejection criteria. IF the R value of a duplicate set falls above the UWL, the Group Leader and analyst are alerted by the QC Coordinator to the possibility of a potential analytical problem. If the R value lies above the UCL the analysis for that parameter is stopped until the problem can be corrected. All affected samples are then repeated.

Tables I through XIII summarize the R and the UCL and the UWL limits for precision. The limits have been calculated for two or more concentration ranges for each parameter required for the Washtenaw County Drain Project. These limits constitute the acceptance/rejection criteria now used by the QC Coordinator to check duplicate sample data.

In a similar fashion, the QC Coordinator records the blind check ampule and/or spiked sample data, received from the Group Leaders on Accuracy Quality Control data sheets. The percent recovery for ampules and/or spikes is then calculated. The control limits for accuracy have been generated from ENCOTEC laboratory performance data. Following the US EPA QC Handbook guidelines, the percent recoveries are averaged over a period of time for each parameter. Control limits are set at ± 3 standard deviations of this average. Warning limits are set at ± 2 standard deviations.

These limits are used by the Coordinator to accept or reject accuracy data that is genrated routinely. If recovery values for a particular analysis lie above or below this control value the analysis is stopped until the problem is rectified. In the case of trace metal analyses by the furance technique, the failure to achieve suitable recoveries would indicate chemical interferences necessitating analysis by standard addiation. The average percent recoveries and control limits for accuracy are presented by parameter in Table XIV.

Another imporatant aspect of the Quality Assurance Program is the frequent participation of the Chemistry Section in US EPA sponsored Performance Evaluations. The ENCOTEC Chemistry Section participated in the Region V CWA V-2-80 Performance Evaluation in the Spring of 1980, and in the Region V SDWA WS 007 Performance Evaluation in the Winter of 1980. The results of these tests were all within the acceptable range and are included herein.

Parameter:

Matrix:

ENVIRONMENTAL CONTROL TECHNOLOGY CORPORATION
ACCURACY QUALITY CONTROL INFORMATION

Sheet #
QA 0300

Entry #	Date of Analysis	Sample Information		Known Conc.	Known Spiked Conc.	Measured Spiked Conc.	Percent Recovery	REMARKS:
		I.D.	Date					

ENVIRONMENTAL CONTROL TECHNOLOGY CORPORATION

PRECISION QUALITY CONTROL INFORMATION

Parameter:
Matrix:

Method:

Sheet #
QA 0200

ENTRY #	DATE OF ANALYSIS	SAMPLE INFORMATION		REPL. 1	REPL. 2	MEAN	% RSD	R	UCL.	QC DECISION
		I.D.	DATE							

TABLE I

PRECISION CONTROL LIMITS
pH
(Standard Units)
Method: US EPA 150.1

Range #	Concentration	$\bar{R}$	UCL	UWL
ALL	ALL	---	*0.33	0.22

* Based on US EPA Average Standard Deviation.

TABLE II

PRECISION CONTROL LIMITS

TOTAL DISSOLVED SOLIDS
(Milligrams Per Liter)
Method: US EPA 160.1

Range #	Concentration	$\bar{R}$	UCL	UWL
1.	0-25	---	---	---
2.	25-100	---	---	---
3.	100-500	10	33	25

TABLE III

PRECISION CONTROL LIMITS

TOTAL SUSPENDED SOLIDS
(Milligrams Per Liter)
Method: US EPA 160.2

Range #	Concentration	$\bar{R}$	UCL	UWL
1.	0-25	0.6	1.9	1.5
2.	25-100	6.6	2.2	17

TABLE IV

PRECISION CONTROL LIMITS

BIOCHEMICAL OXYGEN DEMAND
(Milligrams Per Liter)
Method: US EPA 405.1

Range #	Concentration	$\bar{R}$	UCL	UWL
1.	0-10	0.44	1.4	1.1
2.	P2C2 (146)	3.6	11.7	9.0

TABLE V

PRECISION CONTROL LIMITS

CHEMICAL OXYGEN DEMAND
(Milligrams Per Liter)
Method: US EPA 410.4

Range #	Concentration	$\bar{R}$	UCL	UWL
1.	5-20	1.4	4.5	3.5
2.	20-50	1.6	5.2	4.0
3.	50-100	---	---	---
4.	100-250	---	---	---

TABLE VI

PRECISION CONTROL LIMITS

NITRATE + NITRITE NITROGEN
(Milligrams Per Liter)
METHOD: US EPA 353.2

Range #	Concentration	$\bar{R}$	UCL	UWL
1.	P2C2 0.38	0.006	0.020	0.015
2.	0-0.050	---	---	---
3.	0.050-0.100	---	---	---
4.	0.100-0.500	0.010	0.033	0.025
5.	0.500-2.00	0.010	0.033	0.025

TABLE VII

PRECISION CONTROL LIMITS

TOTAL KJELDAHL NITROGEN
(Milligrams Per Liter)
Method: US EPA 351.1

Range #	Concentration	$\bar{R}$	UCL	UWL
1.	0.01-0.10	---	---	---
2.	0.10-0.50	---	---	---
3.	0.50-2.00	0.12	0.40	0.031
4.	2.00-10.0	---	---	---
5.	P2C4 3.51	0.17	0.57	0.44

TABLE VIII

PRECISION CONTROL LIMITS

TOTAL PHOSPHORUS
(Milligrams Per Liter)
Method: US EPA 365.1

Range #	Concentration	$\bar{R}$	UCL	UWL
1.	0-0.05	0.002	0.007	0.006
2.	0.05-0.20	0.005	0.018	0.013
3.	0.20-0.60	0.011	0.035	0.027
4.*	0.60-1.20	0.022	0.072	0.055

* By Regression analysis.

TABLE IX

PRECISION CONTROL LIMITS

TOTAL CADMIUM
(Micrograms Per Liter)
Method: US EPA 213.2

Range #	Concentration	$\bar{R}$	UCL	UWL
1.	0-1	0.09	0.29	0.22
2.	1-10	0.13	0.43	0.33
3.	10-25	---	---	---

TABLE X

PRECISION CONTROL LIMITS

TOTAL CHROMIUM
(Micrograms Per Liter)
Method: US EPA 218.2

Range #	Concentration	$\overline{R}$	UCL	UWL
1.	1-10	0.7	2.2	1.7
2.	10-25	0.9	2.9	2.2
3.	25-60	4.0	13	10
4.	60-150	---	---	---

TABLE XI

PRECISION CONTROL LIMITS

TOTAL IRON
(Milligrams Per Liter)
Method: US EPA 236.1

Range #	Concentration	$\overline{R}$	UCL	UWL
1.	0-0.05	0.010	0.033	0.025
2.	*0.05-0.20	0.013	0.043	0.033
3.	0.20-0.50	0.021	0.067	0.52
4.	0.50-1.00	0.041	0.13	0.10
5.	1.00-5.00	---	---	---

* By regression analysis.

TABLE XII

PRECISION CONTROL LIMITS

TOTAL LEAD
(Micrograms Per Liter)
Method: US EPA 239.2

Range	Concentration	$\bar{R}$	UCL	UWL
1.	0-10	0.3	1.1	0.8
2.	10-25	1.2	3.8	3.0
3.	25-60	4.6	14.9	11.5
4.	60-150	---	---	---
PlC1 (4 ug/l)		0.5	1.6	1.2

TABLE XIII

PRECISION CONTROL LIMITS
TOTAL ZINC
(Milligrams Per Liter)
Method: US EPA 289.1

Range #	Concentration	$\bar{R}$	UCL	UWL
1.	.005-.030	.001	.003	.003
2.	.03-0.10	.003	.008	.006
3.	.10-.50	.002	.007	.005
4.	.50-1.0	---	---	---
5.	1.0-5.0	---	---	---

ACCURACY CONTROL LIMITS

Parameter	Method #	Average Percent Recovery	Standard Deviation	Control Limits
Biochemical Oxygen Demand (US EPA Q.C. Check P2C2 146 mg/l)	US EPA 405.1	86.2%	±4.5%	72.7% - 99.7%
Nitrate + Nitrite Nitrogen (US EPA Q.C. Check P2C2 0.38 mg/l)	US EPA 353.2	98.3%	±4.2%	85.7% - 111%
Total Kjeldahl Nitrogen (US EPA Check P2C4 3.51 mg/l)	US EPA 351.1	98.5%	±4.4%	85.3% - 112%
Total Phosphorus (US EPA Q.C. Check P2C4 0.66 mg/l	US EPA 365.1	96.0%	±3.6%	85.2% - 107%
Total Cadmium (US EPA Q.C. Check P2C2 0.059 mg/l)	US EPA 213.1 (A.A. - Direct Aspiration)	96.0%	±7.0%	75% - 117%
Total Cadmium US EPA Q.C Check P1C1 2.0 ug/l)	US EPA 213.2 (A.A. - Furnace Technique	92.5%	±6.6%	72.7% - 112%
Total Chromium (US EPA Q.C. Check P2C2 0.304 mg/l	US EPA 218.1 (A.A. - Direct Aspiration)	100%	±5.2%	84.4% - 116%
Total Chromium (US EPA Q.C. Check P1C2 7 ug/l)	US EPA 218.2 (A.A. - Furnace Technique)	103%	±8.7%	76.9% - 129%
Total Iron (US EPA Q.C. Check P2C2 0.796 mg/l)	US EPA 236.1 (A.A. - Direct Aspiration)	103%	±4.0%	
Total Lead (U.S. EPA Q.C. Check P1C1 4 ug/l)	US EPA 239.2 (A.A. Furnace Technique)	84.2%	±9.0%	
Total Zinc (U.S. EPA Q.C Check P2C3 0.478 mg/l)	US EPA 289.1 (A.A. - Direct Aspiration)	99.7%	±2.1%	

I

PERFORMANCE EVALUATION REPORT DATE: 2/1

WATER SUPPLY STUDY NUMBER WS007

LABORATORY: K1009 (ENCOTEC)

PARAMETER	SAMPLE NUMBER	REPORTED VALUE		TRUE VALUE	ACCEPTANCE LIMITS	PERFORMANC EVALUATIO
ALL VALUES IN MICROGRAMS PER LITER (EXCEPT AS NOTED)						
ARSENIC	1	43		39.9	28.- 51.	ACCEPTABL
	2	70		60.9	47.- 75.	ACCEPTABL
BARIUM	1	136	*	113	70.-180.	ACCEPTABL
	2	470		450	350.-570.	ACCEPTABL
CADMIUM	1	2.0		1.70	.40- 4.0	ACCEPTABL
	2	17.0	*	17.0	11.- 20.	ACCEPTABL
CHROMIUM	1	37		33.5	23.- 44.	ACCEPTABL
	2	100		101.	83.-120.	ACCEPTABL
LEAD	1	31		26.4	15.- 39.	ACCEPTABL
	2	54		45.7	32.- 60.	ACCEPTABL
MERCURY	1	0.5		0.52	.23- .79	ACCEPTABL
	2	2.2		2.19	1.2- 3.1	ACCEPTABL
SELENIUM	1	4		5.41	2.6- 9.1	ACCEPTABL
	2	10		14.1	7.0- 20.	ACCEPTABL
SILVER	1	35		32.0	19.- 45.	ACCEPTABL
	2	88		82.0	64.- 97.	ACCEPTABL
NITRATE AS N	1	0.33		0.33	.23- .43	ACCEPTABL
(MILLIGRAMS PER LITER)	2	10.9		10.8	9.7- 12.	ACCEPTABL
FLUORIDE	1	0.64		0.65	.53- .76	ACCEPTABL
(MILLIGRAMS PER LITER)	2	1.25		1.30	1.1- 1.5	ACCEPTABL
ENDRIN	1	3.6		3.63	1.9- 5.2	ACCEPTABL
	2	1.1		1.21	.53- 1.8	ACCEPTABL
LINDANE	1	6.7		7.04	4.0- 9.2	ACCEPTABL
	2	0.08	*	0.084	.033- .17	ACCEPTABL
METHOXYCHLOR	1	49		47.1	27.- 64.	ACCEPTABL
	2	0.67		0.75	.23- 1.3	ACCEPTABL
TOXAPHENE	3	5.8		5.61	1.5- 8.6	ACCEPTABL
	4	13.2		14.0	2.6- 23.	ACCEPTABL
2,4-D	1	106	*	90.7	21.-130.	ACCEPTAB
	2	2.0		1.81	.044- 3.3	ACCEPTAB

* SIGNIFICANT GENERAL METHOD BIAS IS ANTICIPATED FOR THIS RESULT

PERFORMANCE EVALUATION REPORT DATE: 2/16/8[illegible]

WATER SUPPLY STUDY NUMBER WS007

LABORATORY: MI009 Environ. Cont. Tech. Corp

PARAMETER	SAMPLE NUMBER	REPORTED VALUE		TRUE VALUE	ACCEPTANCE LIMITS	PERFORMANCE EVALUATION
ALL VALUES IN MICROGRAMS PER LITER (EXCEPT AS NOTED)						
2,4,5-TP (SILVEX)	1	7.2		7.13	2.1- 11.	ACCEPTABLE
	2	1.4		1.19	.004- 2.0	ACCEPTABLE
CHLOROFORM	1	16.9		14.9	12.- 18.	ACCEPTABLE
	2	51.6		44.7	36.- 54.	ACCEPTABLE
BROMOFORM	1	27		24.5	20.- 29.	ACCEPTABLE
	2	72		61.4	49.- 74.	ACCEPTABLE
BROMODICHLOROMETHANE	1	106		94.4	76.-110.	ACCEPTABLE
	2	21.6		18.9	15.- 23.	ACCEPTABLE
DIBROMOCHLOROMETHANE	1	13		11.3	9.0- 14.	ACCEPTABLE
	2	98		84.8	68.-100.	ACCEPTABLE
TOTAL TRIHALOMETHANE	1	163.		145.1	120.-170.	ACCEPTABLE
	2	243.		209.8	170.-250.	ACCEPTABLE
TURBIDITY (NTU'S)	1	3.7	*	3.50	2.9- 4.7	ACCEPTABLE
	2	0.80	*	0.600	.34- 1.1	ACCEPTABLE

*, SIGNIFICANT GENERAL METHOD BIAS IS ANTICIPATED FOR THIS RESULT

US ENVIRONMENTAL PROTECTION AGENCY
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY-CINCINNATI

EVALUATION TERMS USED FOR PERFORMANCE EVALUATION STUDIES

ACCEPTANCE LIMITS--DATA FALLING WITHIN THIS INTERVAL ARE ACCEPTABLE.

FOR EACH SAMPLE, THIS IS A 99 PERCENT CONFIDENCE INTERVAL CALCULATED FROM DATA OF PREVIOUS EPA METHOD STUDIES OR FROM SIMILAR INTERLABORATORY DATA. BY DEFINITION THE ANALYTICAL RESULTS FROM A LABORATORY PRODUCING VALID DATA SHOULD FALL WITHIN THE ACCEPTANCE LIMITS 99 TIMES OUT OF EVERY 100 ANALYSES.

WARNING LIMITS--DATA FALLING OUTSIDE THIS INTERVAL SHOULD BE REVIEWED FOR PROBLEMS.

FOR EACH SAMPLE, THIS IS THE SMALLER OF TWO 95 PERCENT CONFIDENCE INTERVALS CALCULATED EITHER DIRECTLY FROM PERFORMANCE EVALUATION DATA OR FROM EPA METHOD STUDY DATA.

PERFORMANCE EVALUATION COMMENTS

THERE ARE FIVE ENTRIES:

(1) ACCEPTABLE--THE REPORTED VALUE WAS WITHIN ALL LIMITS.
(2) NOT ACCEPTABLE--THE REPORTED VALUE WAS BEYOND ALL LIMITS.
(3) CHECK FOR ERROR--THE REPORTED VALUE WAS WITHIN THE ACCEPTANCE LIMITS, BUT OUTSIDE OF THE WARNING LIMITS.
(4) UNUSABLE DATA--THE REPORTED VALUE WAS PROVIDED IN A FORM THAT COULD NOT BE ANALYZED OR THE ANALYSIS WAS NOT DONE ACCORDING TO THE INSTRUCTIONS.
(5) DASH LINE(---) --NO DATA REPORTED.

ANY PERFORMANCE EVALUATION OTHER THAN ACCEPTABLE REQUIRES A REVIEW TO DETERMINE THE CAUSE AND CORRECTION OF DEFICIENCIES OR ERRORS.

PERFORMANCE EVALUATION REPORT

DATE:

WATER POLLUTION STUDY NUMBER: V-2-80

ABORATORY: Environmental Control Technology Corporation (ENCOTEC)

ARAMETER	SAMPLE NUMBER	REPORTED VALUE	TRUE VALUE	ACCEPTANCE LIMITS	WARNING LIMITS	PERFORMANCE EVALUATION
TRACE METALS IN MICROGRAMS PER LITER						
UMINUM	1	77	80.0	0.-156.	19.5-126.	Acceptable
	2	450	450.0	261.-652.	345.-569.	Acceptable
SENIC	1	23	18.0	1.31-34.2	5.49-30.0	Acceptable
	2	74	60.0	18.5-101.	29.4-90.4	Acceptable
RYLLIUM	1	13	10.0	0.-32.0	0.-21.9	Acceptable
	2	250	250.0	172.-329.	216.-285.	Acceptable
DMIUM	1	2.0	1.5	0.-7.41	0.-4.63	Acceptable
	2	14	13.0	5.94-19.9	9.07-16.8	Acceptable
BALT	1	10	10.0	0.-23.7	0.-19.8	Acceptable
	2	81	80.0	48.0-108.	55.8-99.9	Acceptable
ROMIUM	1	9	7.0	0.-21.0	2.14-11.8	Acceptable
	2	98	80.0	41.5-113.	55.5-98.8	Acceptable
PPER	1	8	8.0	0.-35.9	0.-27.2	Acceptable
	2	49	50.0	19.1-85.5	30.4-74.2	Acceptable
ON	1	16	17.0	0.-76.9	0.-63.3	Acceptable
	2	83	80.0	20.2-150.	31.9-138.	Acceptable
RCURY	1	0.6	0.67	0.-1.88	.010-1.62	Acceptable
	2	3.0	3.5	0.-6.86	.597-5.84	Acceptable
NGANESE	1	12	11.0	0.-28.2	5.05-18.6	Acceptable
	2	82	75.0	48.2-102.	58.8-91.6	Acceptable
CKEL	1	18	20.0	0.-44.5	1.58-36.6	Acceptable
	2	82	80.0	38.4-121.	54.7-104.	Acceptable
AD	1	19	18.0	0.-50.2	0.-42.5	Acceptable
	2	140	120.0	67.9-172.	82.1-158.	Acceptable
LENIUM	1	2	3.8	0.-11.7	0.-9.79	Acceptable
	2	15***	30.0	.140-53.0	7.27-45.8	Acceptable
NADIUM	1	61	60.0	0.-162.	0.-135.	Acceptable
	2	240	250.0	105.-404.	144.-365.	Acceptable
NC	1	16	12.0	0.-45.7	0.-33.0	Acceptable
	2	80	80.0	41.0-126.	55.6-111.	Acceptable

***50% recovery. This can be improved.

PERFORMANCE EVALUATION REPORT DATE:

WATER POLLUTION STUDY NUMBER V-2-80

LABORATORY: Environmental Control Technology Corporation (EMCOTEC)

PARAMETER	SAMPLE NUMBER	REPORT VALUE	TRUE VALUE	ACCEPTANCE LIMITS	WARNING LIMITS	PERFORMANCE EVALUATION
MINERALS IN MILLIGRAMS PER LITER (EXCEPT AS NOTED)						
PH-UNITS	1	7.70	7.6	6.19-8.40	6.46-8.13	Acceptable
	2	8.52	8.4	7.56-8.71	7.70-8.57	Acceptable
SPEC. COND.	1	118	119.	70.9-169.	83.0-157.	Acceptable
(UMHOS AT 25 C)	2	525	505.	340.-636.	377.-600.	Acceptable
TDS AT 180 C	1	68	58.1	23.7-99.3	33.0-90.0	Acceptable
	2	296	298.	246.-370.	261.-355.	Acceptable
TOTAL HARDNESS	1	25	26.5	19.4-34.2	21.2-32.4	Acceptable
(AS $CACO_3$)	2	121	123.	103.-140.	108.-135.	Acceptable
CALCIUM	1	5.7	6.0	3.71-8.72	4.33-8.10	Acceptable
	2	34.2	34.2	20.8-45.8	23.9-42.7	Acceptable
MAGNESIUM	1	2.6	2.8	1.65-3.94	1.93-3.65	Acceptable
	2	8.7	9.2	5.28-12.7	6.21-11.8	Acceptable
SODIUM	1	6.8	6.1	3.94-8.21	4.47-7.67	Acceptable
	2	43.3	41.7	31.1-51.4	33.7-48.9	Acceptable
POTASSIUM	1	1.7	1.5	1.07-1.94	1.18-1.83	Acceptable
	2	9.7	7.9	4.96-11.2	5.74-10.4	Acceptable
TOTAL ALKALINITY	1	15	14.4	7.14-22.8	9.06-20.9	Acceptable
(AS $CACO_3$)	2	78	79.3	65.4-88.3	68.2-85.5	Acceptable
CHLORIDE	1	18.	19.1	11.1-28.8	13.3-26.7	Acceptable
	2	72	75.3	64.7-87.5	67.5-84.7	Acceptable
FLUORIDE	1	.48	0.56	.389-.755	.435-.709	Acceptable
	2	1.86	1.9	1.46-2.34	1.57-2.23	Acceptable
SULFATE	1	13	13.3	8.87-17.0	9.87-16.0	Acceptable
	2	80	80.3	63.6-92.0	67.1-88.5	Acceptable

PERFORMANCE EVALUATION REPORT DATE:

WATER POLLUTION STUDY NUMBER V-2-80

LABORATORY: Environmental Control Technology Corporation (ENCOTEC)

PARAMETER	SAMPLE NUMBER	REPORTED VALUE	TRUE VALUE	ACCEPTANCE LIMITS	WARNING LIMITS	PERFORMANCE EVALUATION
NUTRIENTS IN MILLIGRAMS PER LITER						
AMMONIA-N	1	0.28	0.27	.142-.418	.175-.385	Acceptable
	2	0.98	0.95	.679-1.22	.749-1.15	Acceptable
NITRATE-N	1	0.26	0.25	.209-.321	.223-.307	Acceptable
	2	1.36	1.37	1.01-1.66	1.18-1.49	Acceptable
ORTHOPHOS.	1	0.02	.023	0 - .056	.011 - .041	Acceptable
	2	0.23	.228	.176 - .284	.195 - .256	Acceptable
KJELDAHL-N	3	0.40	0.45	0.-1.03	.163-.801	Acceptable
	4	1.15	1.13	.383-1.87	.662-1.59	Acceptable
TOTAL P	3	0.13	0.120	.028-.242	.125-.165	Acceptable
	4	0.44	0.428	.185-.673	.278-.580	Acceptable
DEMANDS IN MILLIGRAMS PER LITER						
COD	1	16.3	8.2	0. - 22.4	0. - 18.8	Acceptable
	2	284	271.	208. - 313.	221. - 300.	Acceptable
TOC	1	3.4	3.2	2.89 - 4.66	3.11 - 4.43	Acceptable
	2	116	107.	62.7 - 143.	73.0 - 133.	Acceptable
5 DAY BOD	1	3	2.5	0. - 5.75	0. - 4.83	Acceptable
	2	143	117.	49.5 - 151.	61.9 - 138.	Check for error

APPENDIX II

APP. II

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MAR 10 1982
Ans'd............

DEPARTMENT OF NATURAL RESOURCES

WATER RESOURCES COMMISSION

GENERAL RULES

Filed with Secretary of State, November 27, 1973

These rules take effect 15 days after filing with the Secretary of State

(By authority conferred on the water resources commission by sections 2 and 5 of Act No. 245 of the Public Acts of 1929, as amended, being sections 323.2 and 323.5 of the Michigan Compiled Laws.)

Part 4. Water Quality Standards, is added to the General Rules of the commission to read as follows:

PART 4. WATER QUALITY STANDARDS

R 323.1041. Purpose

Rule 1041. It is the purpose of the water quality standards as prescribed by these rules to establish water quality requirements applicable to the Great Lakes, their connecting waterways and all other surface waters of the state, which shall protect the public health and welfare, enhance and maintain the quality of water, serve the purposes of United States Public Law 92-500 and the commission act; and which shall protect the quality of waters for recreational purposes, public and industrial water supplies,, agriculture uses, navigation and propagation of fish, other aquatic life and wildlife.

R 323.1043. Definitions A to N.

Rule 1043. As used in this part:

(a) "Agricultural water use" means a use of water for agricultural purposes, including but not limited to livestock watering, irrigation and crop spraying.

(b) "Application factor" means a numerical factor applied to the TL$_m$, or concentration producing other effect end points to provide the concentration of a toxic substance that would be safe for test organisms in the waters of the state.

(c) "Best practicable waste treatment technology for control of total phosphorus" means chemical-physical or chemical-physical-biological treatment processes, including but not limited to treatment with aluminum salts, iron salts or lime in conjunction with appropriate coagulant chemicals, settling or filtration or both, with operation and management of the treatment facilities and the process to achieve optimum phosphorus removal rates, or equivalent treatment.

(d) "Anadromous salmonids" means those trout and salmon which ascend streams to spawn.

(e) "Coldwater fish" means those fish species whose populations thrive in relatively cold water, including but not limited to trout, salmon, whitefish and cisco.

(f) "Connecting waterways" means the St. Marys river, Keweenaw waterway, Detroit river, St. Clair river and lake St. Clair.

(g) "Designated use" means a use of the waters of the state as established by these rules, including but not limited to industrial, agricultural and public water supply; recreation; fish, other aquatic life and wildlife; and navigation.

(h) "Dissolved oxygen" means the amount of oxygen dissolved in water, commonly expressed as a concentration in terms of milligrams per liter.

(i) "Dissolved solids" means the amount of materials dissolved in water commonly expressed as a concentration in terms of milligrams per liter.

(j) "Effluent" means a wastewater discharged from a point source to the waters of the state.

(k) "Fecal coliform" means a type of coliform bacteria found in the intestinal tract of humans and other warm-blooded animals.

(l) "Fish, other aquatic life and wildlife use" means the use of the waters of the state by fish, other aquatic life and wildlife for any life history stage or activity.

(m) "Industrial water supply" means a water source not protected for public water supply and intended for use in commercial or industrial applications and non-contact food processing.

(n) "Mixing zone" means a region of a water body which receives a wastewater discharge of a different quality than the receiving waters, and within which the water quality standards as prescribed by these rules do not apply.

(o) "Natural water temperature" means the temperature of a body of water without an influence from an artificial source, or a temperature as otherwise determined by the commission.

R 323.1044. Definitions P to W

Rule 1044. As used in this part:

(a) "Palatability" means the state of being agreeable or acceptable to the senses of sight, taste or smell.

(b) "Plant nutrients" means those chemicals, including but not limited to nitrogen and phosphorus, necessary for the growth and reproduction of aquatic rooted, attached and floating plants, fungi or bacteria.

(c) "Point source" means a discernible, confined and discrete conveyance, from which wastewater is or may be discharged to the waters of the state including but not limited to a pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, concentrated animal feeding operation or vessel or other floating craft.

(d) "Public water supply" means a surface raw water source which, after conventional treatment, will provide a safe, clear, potable and aesthetically pleasing water for uses which include but are not limited to human consumption, food processing and cooking and as a liquid ingredient in foods and beverages.

(e) "Raw water" means the waters of the state prior to any treatment.

(f) "Receiving waters" means the waters of the state into which an effluent is or may be discharged.

(g) "Sanitary sewage" means treated or untreated wastewaters which contain human metabolic and domestic wastes.

(h) "Standard" means a definite numerical value or narrative statement promulgated by the commission to enhance or maintain water quality to provide for and fully protect a designated use of the waters of the state.

(i) "Suspended solids" means the amount of material suspended in water, commonly expressed as a concentration in terms of milligrams per liter.

(j) "TL_m" means median tolerance limit which is the concentration of a test material in a suitable diluent at which 50% of the exposed organisms survive for a specified period of exposure.

(k) "Total body contact recreation" means an activity where the human body may come into direct contact with water to the point of complete submergence, including but not limited to activities such as swimming, water skiing and skin diving.

(l) "Toxic substance" means a substance of unnatural origin, except heat, in concentrations or combinations which are or may become harmful to plant or animal life.

(m) "Warmwater fish" means those fish species whose populations thrive in relatively warm water, including but not limited to bass, pike, walleye and panfish.

(n) "Wastewater" means liquid waste resulting from commercial, municipal and domestic operations and industrial processes, including but not limited to cooling and condensing waters, sanitary sewage and industrial waste.

(o) "Waters of the state" means the Great Lakes, their connecting waterways, all inland lakes, rivers, streams, impoundments, open drains and other surface watercourses within the confines of the state, except drainage ways and ponds used solely for wastewater conveyance, treatment or control.

R 323.1050. Suspended solids.

Rule 1050. All waters of the state shall contain no unnatural turbidity, color, oil films, floating solids, foams, settleable solids or deposits in quantities which are or may become injurious to any designated use.

R. 323.1051. Dissolved solids.

Rule 1051. (1) The addition of any dissolved solids shall not exceed concentrations which are or may become injurious to any designated use. Point sources containing dissolved solids shall be considered by the commission on a case-by-case basis and increases of dissolved solids in the waters of the state shall be limited through the application of best practicable control technology currently available as prescribed by the administrator of the United States environmental protection agency pursuant to section 304 (b) of United States Public Law 92-500, except that in no instance shall total dissolved solids in the waters of the state exceed a concentration of 500 milligrams per liter as a monthly average nor more than 750 milligrams per liter at any time, as a result of controllable point sources.

(2) In addition to the standards prescribed by subrule (1), waters of the state used for public water supply shall, at the point of water intake, not exceed the permissible inorganic and organic chemicals criteria for raw public water supply in "Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, 1968", except chlorides. For the Great Lakes and connecting waters, chlorides shall, at the point of water intake, not exceed 50 milligrams per liter as a monthly average. For all other waters of the state, chlorides shall, at the point of water intake, not exceed 125 milligrams per liter as a monthly average.

R 323.1053. Hydrogen ion concentration.

Rule 1053. The hydrogen ion concentration expressed as pH shall be maintained within the range of 6.5 to 8.8 in all waters of the state except as otherwise prescribed by rule 1080. Any artificially induced variation in the natural pH shall remain within this range and shall not exceed 0.5 units of pH.

R 323.1055. Taste and odor producing substances.

Rule 1055. The waters of the state shall contain no unnatural substances in concentrations which are or may become injurious to their use for public, industrial or agricultural water supply, or in concentrations which lower the palatability of fish as measured by test procedures acceptable to the commission.

R 323.1057. Toxic substances

Rule 1057. (1) Toxicity of undefined toxic substances not specifically included in subrules (2) and (3) shall be determined by development of 96 hour TL_m's or other appropriate effect end points obtained by continuous-flow or *in situ* bioassays using suitable test organisms. Concentrations of undefined toxic substances in the waters of the state shall not exceed safe concentrations as determined by applying an application factor, based on knowledge of the behavior of the toxic substances and the organisms to be protected in the environment, to the TL_m or other appropriate effect end point.

(2) For all waters of the state, unless on the basis of recent information a more restrictive limitation is required to protect a designated use, concentrations of defined toxic substances, including heavy metals, shall be limited by application of the toxic substances recommendations contained in the chapter on Freshwater Organisms, "Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, 1968", or by application of any toxic effluent standard, limitation or prohibition promulgated by the administrator of the United States environmental protection agency pursuant to section 307 (a) of the United States Public Law 92-500, whichever is more restrictive.

(3) In addition to the standards prescribed in subrules (1) and (2), waters of the state used for public water supply shall, at the point of water intake, not exceed the permissible inorganic and organic chemicals criteria for raw public water supply in "Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, 1968", except that chlorides shall be limited to the same extent as prescribed by rule 1051(2).

R 323.1058. Radioactive substances.

Rule 1058. The control and regulation of radioactive substances discharged to the waters of the state shall be in accordance with and subject to the criteria, standards or requirements prescribed by the United States atomic energy commission as set forth in the applicable Code of Federal Regulations, Title 10, Part 20.

R 323.1060. Plant nutrients.

Rule 1060. Nutrients originating from domestic, industrial, municipal or domestic animal sources shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached and floating plants, fungi or bacteria which are or may become injurious to the designated uses of the waters of the state. Phosphorus which is or may readily become available as a plant nutrient shall be controlled from point source discharges by the application of methods utilizing best practicable waste treatment technology for control of total phosphorus, with the goal of achieving a monthly average effluent concentration of one milligram per liter as P.

R 323.1062. Fecal coliform.

Rule 1062. (1) Waters of the state protected for total body contact recreation shall contain not more than 200 fecal coliforms per 100 milliliters; and all other waters of the state shall contain not more than 1,000 fecal coliforms per 100 milliliters. These concentrations may be exceeded if due to uncontrollable non-point sources.

(2) Compliance with the fecal coliform standards prescribed by subrule (1) shall be determined on the basis of the geometric average of any series of 5 or more consecutive samples taken over not more than a 30-day period.

R 323.1064. Dissolved oxygen; Great Lakes, connecting waterways and inland streams.

Rule 1064. A minimum of 6 milligrams per liter of dissolved oxygen in all Great Lakes and connecting waterways shall be maintained and, except for inland lakes as prescribed in rule 1065, a minimum of 6 milligrams per liter of dissolved oxygen shall be maintained at all times in all inland streams designated by these rules to be protected for coldwater fish. In all other waters, except for inland lakes as prescribed by rule 1065, a minimum of 5 milligrams per liter of dissolved oxygen shall be maintained as a daily average and no single value shall be less than 4 milligrams per liter in waters naturally capable of supporting warmwater fish.

R 323.1065. Dissolved oxygen; inland lakes.

Rule 1065. (1) The following standards for dissolved oxygen shall apply to inland lakes capable of supporting coldwater fish:

(a) In warmwater inland lakes with little water exchange which are capable of sustaining a cold stratum of well-oxygenated water throughout the summer above a hypolimnion with very little oxygen, a minimum of 6 milligrams per liter of dissolved oxygen shall be maintained throughout the epilimnion and the upper one-third of the thermocline during the entire summer stagnation period. At all other times, the dissovled oxygen concentration shall be maintained at natural levels.

(b) In inland lakes capable of sustaining high oxygen values throughout the hypolimnion during periods of stagnation, dissolved oxygen concentrations greater than 6 milligrams per liter shall be maintained throughout the entire lake.

(c) In inland lakes which serve a principal anadromous fish migration routes, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained throughout the epilimnion and the upper one-third of the thermocline in stratified lakes throughout periods of fish migration. In unstratified lakes, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained throughout the entire lake during periods of fish migration.

(d) In shallow, unstratified coldwater inland lakes, dissolved oxygen concentrations greater than 6 milligrams per liter shall be maintained throughout the entire lake.

(2) The following standards for dissolved oxygen shall apply to inland lakes capable of supporting warmwater fish.

(a) In warmwater lakes with little water exchange, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained throughout the epilimnion and the upper one-third of the thermocline during the entire summer stagnation period. At all other times, dissolved oxygen concentrations shall be maintained at natural levels.

(b) In warmwater lakes with a high rate of water exchange, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained throughout the epilimnion and the upper one-third of the thermocline during the summer stagnation period. At all other times, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained except in areas where natural oxygen depressions occur.

R 323.1069. Temperature; general considerations.

Rule 1069. (1) In all waters of the state, the points of temperature measurement normally shall be in the surface 1 meter; however, where turbulence, sinking plumes, discharge inertia or other phenomena upset the natural thermal distribution patterns of receiving waters, temperature measurements shall be required to identify the spatial characteristics of the thermal profile.

(2) Monthly maximum temperatures, based on the ninetieth percentile occurrence of natural water temperatures plus the increase allowed at the edge of the mixing zone and in part on long-term physiological needs of fish, may be exceeded for short periods when natural water temperatures exceed the ninetieth percentile occurrence. Temperature increases during these periods may be permitted by the commission, but in all cases shall not be greater than the natural water temperature plus the increase allowed at the edge of the mixing zone.

(3) Natural daily and seasonal temperature fluctuations of the receiving waters shall be preserved.

R 323.1070. Temperature; Great Lakes and connecting waterways.

Rule 1070. (1) The Great Lakes and connecting waterways shall not receive a heat load which would warm the receiving water at the edge of the mixing zone more than 3 degrees Fahrenheit above the existing natural water temperature.

(2) The Great Lakes and connecting waterways shall not receive a heat load which would warm the receiving water at the edge of the mixing zone to temperatures in degrees Fahrenheit higher than the following monthly maximum temperatures:

(a) Lake Michigan north of a line due west from the city of Pentwater:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	40	50	55	70	75	75	75	65	60	45

(b) Lake Michigan south of a line due west from the city of Pentwater:

J	F	M	A	M	J	J	A	S	O	N	D
45	45	45	55	60	70	80	80	80	65	60	50

(c) Lake Superior and the St. Marys River:

J	F	M	A	M	J	J	A	S	O	N	D
38	36	39	46	53	61	71	74	71	61	49	42

(d) Lake Huron north of a line due east from Tawas Point:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	40	50	60	70	75	80	75	65	55	45

(e) Lake Huron south of a line due east from Tawas Point, except Saginaw bay:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	40	55	60	75	80	80	80	65	55	45

(f) Lake Huron, Saginaw bay:

J	F	M	A	M	J	J	A	S	O	N	D
45	45	45	60	70	75	80	85	78	65	55	45

(g) St. Clair river:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	40	50	60	70	75	80	75	65	55	50

(h) Lake St. Clair:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	45	55	70	75	80	83	80	70	55	45

(i) Detroit river:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	45	60	70	75	80	83	80	70	55	45

(j) Lake Erie:

J	F	M	A	M	J	J	A	S	O	N	D
45	45	45	60	70	75	80	85	80	70	60	50

R 323.1072. Temperature: inland lakes, general standards.

Rule 1072. Inland lakes shall not receive a heat load which would:

(a) Increase the temperature of the thermocline or hypolimnion or decrease the volume thereof.

(b) Increase the temperature of the receiving waters at the edge of the mixing zone more than 3 degrees Fahrenheit above the existing natural water temperature.

(c) Increase the temperature of the receiving waters at the edge of the mixing zone to temperatures greater than the following monthly maximum temperatures:

J	F	M	A	M	J	J	A	S	O	N	D
45	45	50	60	70	75	80	85	80	70	60	50

R 323.1073. Temperature; inland lakes, anadromous salmonid migrations.

Rule 1073. Warmwater inland lakes which serve as principal migratory routes for anadromous salmonids shall not receive a heat load during periods of migration at such locations and in a manner which may adversely affect salmonid migration or raise the receiving water temperature at the edge of the mixing zone more than 3 degrees Fahrenheit above the existing natural water temperature.

R 323.1074. Impoundments.

Rule 1074. (1) River and stream standards as prescribed by rule 1075 shall apply to all impoundments.

(2) The commission shall determine, when necessary, whether a body of water shall be considered as an inland lake or an impoundment for the purpose of these rules. This determination shall be made partially on the basis of aquatic life resources to be protected.

R 323.1075. Temperature; rivers and streams.

Rule 1075. (1) Rivers and streams naturally capable of supporting coldwater fish shall not receive a heat load which would:

(a) Increase the temperature of the receiving waters at the edge of the mixing zone more than 2 degrees Fahrenheit above the existing natural water temperature.

(b) Increase the temperature of the receiving waters at the edge of the mixing zone to temperatures greater than the following monthly maximum temperatures:

J	F	M	A	M	J	J	A	S	O	N	D
38	38	43	54	65	68	68	68	63	56	48	40

(2) Rivers and streams naturally capable of supporting warmwater fish shall not receive a heat load which would warm the receiving water at the edge of the mixing zone more than 5 degrees Fahrenheit above the existing natural water temperature.

(3) Rivers and streams naturally capable of supporting warmwater fish shall not receive a heat load which would warm the receiving water at the edge of the mixing zone to temperatures greater than the following monthly maximum temperatures:

(a) Rivers and streams north of a line between Bay City, Midland, Alma and North Muskegon:

J	F	M	A	M	J	J	A	S	O	N	D
38	38	41	56	70	80	83	81	74	64	49	39

(b) Rivers and streams south of a line between Bay City, Midland, Alma and North Muskegon, except the St. Joseph river:

J	F	M	A	M	J	J	A	S	O	N	D
41	40	50	63	76	84	85	85	79	68	55	43

APP # 9

(c) St. Joseph river:

J	F	M	A	M	J	J	A	S	O	N	D
50	50	55	65	75	85	85	85	85	70	60	50

(4) Non-trout rivers and streams that serve as principal migratory routes for anadromous salmonids shall not receive a heat load during periods of migration at such locations and in a manner which may adversely affect salmonid migration or raise the receiving water temperature at the edge of the mixing zone more than 5 degrees Fahrenheit above the existing natural water temperature.

R 323.1080. Special conditions

Rule 1080. To be consistent with the agreement between the United States of America and Canada on Great Lakes water quality effective April 15, 1972, the following conditions shall apply to the Michigan waters of the Great Lakes and their connecting waterways:

(a) Values of pH shall not be outside the range of 6.7 to 8.5.

(b) In Lake Erie, the level of total dissolved solids shall not be greater than 200 milligrams per liter.

(c) Filtrable iron shall not be greater than 0.3 milligrams per liter.

R 323.1082. Mixing zones.

Rule 1082. (1) A mixing zone to achieve a mixture of a point source discharge with the receiving waters shall be considered a region in which organism response to water quality characteristics is time-dependent. Exposure in mixing zones shall not cause an irreversible response which results in deleterious effects to populations of important aquatic life and wildlife. As a minimum restriction the toxic substance 96 hour TL_m for important species of fish or fishfood organisms shall not be exceeded in the mixing zone at any point inhabitable by these organisms, unless it can be demonstrated to the commission that a higher concentration is acceptable. The mixing zone at any transect of a stream shall contain not more than 25% of the cross-sectional area or volume of flow of the stream or both unless it can be demonstrated to the commission that designation of a greater area or volume of streamflow will allow passage of fish and fishfood organisms so that effects on their immediate and future populations are negligible or not measureable. Watercourses or portions thereof which, without one or more point source discharges, would have no flow except during periods of surface runoff may be considered as a mixing zone for a point source discharge. For Lake Michigan, mixing zones shall not exceed a defined area equivalent to that of a circle of radius of 1,000 feet unless the discharger can demonstrate to the commission that the defined area for a thermal discharge is more stringent than necessary to assure the protection and propagation of a balanced indigenous population of aquatic life and wildlife in the receiving water.

(2) All mixing zones established by the commission pursuant to subrule (1) shall be determined on a case-by-case basis.

R 323.1090 Application of water quality standards.

Rule 1090. (1) The water quality standards prescribed by these rules for the various designated uses of the waters of the state apply to receiving waters and are not to be considered applicable to wastewater effluents. The water quality standards shall not apply within defined mixing zones, except for those standards prescribed in rule 1050 for settleable solids, deposits,, floating solids and oil films.

(2) The accepted design streamflow to which the water quality standards as prescribed by these rules shall apply are those equal to or exceeding the 10-year recurrance of a minimum low flow average of 7-day duration, except where the commission determines that a more restrictive application is necessary to protect a particular designated use.

R 323.1091. Designated use interruption.

Rule 1091. Protection of the waters of the state designated for total body contact recreation by the water quality standards prescribed by these rules may be subject to temporary interruption during or following flood conditions or uncontrollable accidents to a sewer or wastewater treatment system. In the event of such an occurrence, full public notice thereof shall be served by the commission to those affected thereby and immediate corrective action shall be required by the commission.

R 323.1092. Dredging.

Rule 1092. The water quality standards prescribed by these rules shall not apply to dredging or construction activities within water areas where such activities occur or during the periods of time when the after effects of dredging or construction activities degrade water quality within such water areas, if the dredging operations or construction have been authorized by the United States army corps of engineers or the department. The water quality standards shall apply, however, in non-confined water areas utilized for the disposal of spoil from dredging operations, except within spoil disposal sites specifically defined by the United States army corps of engineers or the department.

R 323.1096. Determinations of compliance.

Rule 1096. Analysis of the waters of the state to determine compliance with the water quality standards prescribed by these rules shall be made according to procedures outlined in the current edition of "Standard Methods for the Examination of Water and Wastewater" as published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation, or other methods prescribed or approved by the commission and the United States environmental protection agency.

R 323.1097. Chemical applications.

Rule 1097. The application of chemicals for water resource management projects in accordance with and subject to state statutory provisions is not subject to the standards prescribed by these rules, but all projects shall be reviewed and approved by the commission prior to chemical applications.

R 323.1098. Nondegradation and water quality improvement.

Rule 1098. (1) Waters of the state in which the existing water quality is better than the water quality standards prescribed by these rules on the date when the standards become effective, shall not be lowered in quality by action of the commission unless and until it has been affirmatively demonstrated to the commission that a change in quality will not become injurious to the public health, safety or welfare; or become injurious to domestic, commercial, industrial, agricultural, recreational or other uses which are being made of the waters; or become injurious to livestock, wild animals, birds, aquatic life or plants, or the growth or propagation thereof be prevented or injuriously affected; or whereby the value of fish or game may be destroyed or impaired, and that a lowering in quality will not be unreasonable and against the public interest in view of the existing conditions in any waters of the state.

(2) Waters of the state which do not meet the water quality standards prescribed by these rules shall be improved to meet those standards. Where the water quality of certain waters of the state do not meet the water quality standards as a result of natural causes or conditions, no further reduction of water quality by controllable point and non-point sources shall be permitted.

R 323.1100. Designated uses, general.

Rule 1100. (1) As a minimum, all waters of the state shall be protected for agricultural uses, navigation, industrial water supply, public water supply at the point of water intake, warmwater fish and partial body contact recreation.

(2) All waters of the state designated as trout streams by the director of the department pursuant to section 8 of Act No. 165 of the Public Acts of 1929, as amended, being section 301.8 of the Michigan Compiled Laws, shall be protected for coldwater fish.

(3) All inland lakes designated or managed as trout lakes by the department and the Great Lakes and their connecting waterways shall be protected for coldwater fish.

R 323.1105. Multiple designated uses.

Rule 1105. When a particular portion of the waters of the state is designated for more than 1 use, the most restrictive water quality standards for one or more of those designated uses shall apply to that portion.

R 323.1110. Designated uses, total body contact recreation.

Rule 1110. (1) The following waters of the state, except in mixing zones prescribed by the commission, shall be protected for total body contact recreation:

(a) All Great Lakes and their connecting waterways.

(b) All inland lakes, including but not limited to those connected to the Great Lakes.

(2) The following rivers and streams and their tributaries, except in mixing zones as prescribed by the commission, shall be protected for total body contact recreation:

(a) All rivers and streams located in the Upper Peninsula.

(b) All rivers and streams located north of, but not including, the Grand and Saginaw river basins.

R 323.1115. Designated uses, impoundments and portions of streams.

Rule 1115. (1) The following impoundments and portions of streams shall be protected for total body contact recreational use:

	Name	Water Impounded	County	Location
(a)	Ada Lake	Thornapple River	Kent	From head of Ada Dam, T. 7 N., R. 10 W Sec. 34 upstream to headwaters of Cascade Lake (48th Street).
(b)	Belleville Lake	Huron River	Wayne	T. 3 S., R. 8 E., Sec. 19 downstream to T. 3 S., R. 8 E., Sec. 24.
(c)	C. S. Mott Lake	Flint River	Genesee	T. 8 N., R. 7 E., Sec. 11, 12, 15, 16, 21.
(d)	Caley Pond	Farmer Creek	Lapeer	T. 6 N., R. 9 E., Sec. 12 and 13.
(e)	Cascade Lake	Thornapple River	Kent	Included in Ada Lake Area
(f)	Fallasberg Dam	Flat River	Kent	T. 7 N., R. 9 W., Sec. 24, 25, 26.
(g)	Ford Lake	Huron River	Washtenaw	T. 3 S., R. 7 E., Sec. 14, 15, 16, 21, 22, 23, 24
(h)	Geddes Pond	Huron River	Washtenaw	T. 2 S., R. 6 E., Sec. 26, 35, 36.
(i)	Grand River	Grand River (not impounded)	Ottawa	Eastmanville T. 7 N., R. 14 W., Sec. 10, downstream to 160th Avenue.
(j)	Grand River	Grand River (not impounded)	Kent	Plainfield Road bridge downstream to lower limits of Comstock Riverside Park, T. 8 N., R. 11 W., Sec. 31.
(k)	Holloway Reservoir	Flint River	Genesee	T. 8 N., R. 8 E., Sec. 1, 2, 11, 12, 13. T. 8 N., R. 9 E., Sec. 7, 8, 17, 18.

(l)	Ionia Recreation Area	Sessions Creek	Ionia	T. 6 N., R. 7 W., Sec. 3 N.W. 1/4 Sec. 3.
(m)	Lake Allegan	Kalamazoo River	Allegan	M-89 bridge downstream to dam - T. 2 N., R. 14 W., Sec. 10.
(n)	Lake Geneva	Looking Glass River (not impounded)	Clinton	T. 5 N., R. 2 W., Sec. 7.
(o)	Lake LeAnn	Grand River	Hillsdale	T. 5 S., R. 1 W., Sec. 3, 4, 9, 10.
(p)	Lake Victoria	Alder Creek	Clinton	T. 6 N., R. 1 W., Sec. 12, 13.
(q)	Lobdell Lake	Shiawassee River	Genesee	T. 5 N., R. 5 E., Sec. 25, 34, 35, 36.
			Livingston	T. 4 N., R. 5 E., Sec. 1 and 2.
(r)	Manitoon Lake	Unnamed Creek	Shiawassee	T. 6 N., R. 2 E., Sec. 10, 11, 14, 15.
(s)	Maple Lake	Paw Paw River	Van Buren	T. 3 S., R. 14 W., Sec. 1, 12.
(t)	Martiny Lake Flooding	S. Branch Chippewa River	Mecosta	T. 15 N., R. 8 W., Sec. 5, 6, 7, 8.
(u)	Moore's Park Impoundment	Grand River	Ingham	Waverly Road bridge downstream to dam, T. 4 N., R. 2 W., Sec. 21.
(v)	Pine Creek Reservoir	Pine Creek	Allegan	T. 1 N., R. 12 W., Sec. 7, 17, 18, 20, 21, 28, 29, 31, 32.
(w)	Ross Lake	North, Middle and South Branches Tobacco River	Gladwin	T. 17 N., R. 2 W., Sec. 1, 2, 11, 12 14. T. 17 N., R. 1 W., Sec. 5, 6, 7.
(x)	Sanford Lake	Tittabawassee River	Midland	T. 15 N., R. 1 W., Sec. 1, 2, 11, 12, 13, 14, 24. T. 16 N., R. 1 W., Sec. 11, 14, 23, 26, 35.
(y)	Secord Lake	Tittabawassee River	Gladwin	T. 19 N., R. 1 E., Sec. 2, 3, 4, 9. T. 20 N., R. 2 E., Sec. 10, 15, 20, 24, 25, 26, 29, 31, 35, 36.

(z)	Shamrock Lake	Tobacco River	Clare	T. 17 N., R. 4 W., Sec. 26.
(aa)	Shiawassee Impoundment	Shiawassee River	Shiawassee	T. 6 N., R. 3 E., Sec. 11, 14.
(bb)	Sleepy Hollow Reservoir	Maple River	Clinton	T. 6 N., R. 1 W., Sec. 3, 10, Jason Rd., downstream to dam
(cc)	Springbrook Lake	Springbrook Creek	Shiawassee	T. 6 N., R. 2 E., Sec. 10.
(dd)	Smallwood Lake	Tittabawassee River	Gladwin	T. 18 N., R. 1 W., Sec. 1. T. 18 N., R. 1 E., Sec. 4, 9, 15, 16. T. 19N., R. 1 W., Sec. 36.
(ee)	Thompson Lake	Bogue Creek	Livingston	T. 3 N., R. 5 E., Sec. 30, 31. T. 3 N., R. 4 E., Sec. 25, 36.
(ff)	Thornapple Lake	Thornapple River	Barry	T. 3 N., R. 7 W., Sec. 19, 20, 30. T. 3 N., R. 8 W., Sec. 24, 25.
(gg)	Thread Lake	Thread Creek	Genesee	T. 7 N., R. 7 E., Sec. 19, 20.
(hh)	Webber Dam Impoundment	Grand River	Ionia	Goodwin Road downstream to dam, T. 7 N., R. 5 W., Sec. 33.
(ii)	Wiggins Lake	Cedar River	Gladwin	T. 18 N., R. 2 W., Sec. 4. T. 19 N., R. 2 W., Sec. 27, 34.
(jj)	Wildwood Lake	Thread Creek	Oakland	T. 5 N., R. 8 E., Sec. 28.
(kk)	Wixom Lake	Tittabawassee River	Gladwin	T. 17 N., R. 1 W., Sec. 36. T. 17 N., R. 1 E., Sec. 1, 2, 11, 12, 13, 14, 23, 26, 27, 33, 34, 35. T. 18 N., R. 1 E., Sec. 25, 36.
			Midland	T. 16 N., R. 1 E., Sec. 2, 3, 4. T. 16 N., R. 1 W., Sec. 1.

(2) The following streams and portions thereof shall be protected for total body contact recreational use:

	Name	County	Location
(a)	Maumee River	Branch, Lenawee and Hillsdale	All water in basin
(b)	St. Joseph River	Berrien	Napier Road to Section line between Section 1, Oronoko Twp., and Sec. 6, Berrien Township.
(c)	St. Joseph River	Berrien	Indiana-Michigan Power Company dam at Berrien Springs to north section line of Section 23, Buchanan Township.
(d)	St. Joseph River	Berrien	Township line between Buchanan and Niles Twps. to sections line between Sections 15 and 16, Nile Township.
(e)	St. Joseph River	Berrien	French Paper Company dam, Niles to Michigan-Indiana border.
(f)	St. Joseph River	Cass and St. Joseph	Michigan-Indiana border to section line between Sections 26 and 27, Constantine Township.
(g)	St. Joseph River	St. Joseph	Michigan Gas and Electri Company dam at Constantine to section line between Sections 19 and 30, Lockport Township.
(h)	St. Joseph River	St. Joseph	Midland Wire Corporation dam at Three Rivers to existing west village limits of Mendon.
(i)	St. Joseph River	St. Joseph	Existing east village limits of Mendon to Sturgeon Lake.
(j)	St. Joseph River	St. Joseph and Branch	Lowland Road to Aborgast Road, Union Township

(k)	St. Joseph River	Branch and Calhoun	Existing east city limits of Union City to existing south village limits of Burlington.
(l)	St. Joseph River	Calhoun	Existing east village limits of Burlington to section line between Sections 33 and 34, Tekonsha Township
(m)	St. Joseph River	Hillsdale	Existing east village limits of Tekonsha to section line between Sections 8 and 9, Litchfield Township.
(n)	St. Joseph River	Hillsdale	Existing east city limi of Litchfield to Genese Mill dam.
(o)	Hickory Creek	Berrien	Mouth at St. Joseph River to section line between Sections 15 and 22, Lincoln Townshi
(p)	Dowagiac River	Cass	City of Niles dam to section line between Sections 9 and 16, Pokagon Township
(q)	East Branch Dowagiac Creek	Cass	Mill pond dam to LaGrange Lake.
(r)	Christiann Creek	Cass	Michigan-Indiana border to Christiann Lake.
(s)	Portage River	St. Joseph	Existing north city limits of Three Rivers to Portage Lake.
(t)	Coldwater River	Branch	Existing east city limits of Union City to Craig Lake.

R 323.1116. Availability of documents.

Rule 1116. Documents referenced in rules 1057 and 1096 may be obtained at current costs as listed as follows:

(a) "Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, 1968" may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402, at a cost of $3.00.

(b) "Standard Methods for the Examination of Water and Wastewater" may be obtained from the American Public Health Association, 1015 Eighteenth Street, N.W., Washington, D. C., 20036, at a cost of $35.00.

PARAMETER	STANDARD	GUIDELINE	NOTE/CRITERIA	APPLICABILITY	SOURCE[1]
Arsenic	100 µg/l		toxicity to aquatic life		1976 STD
Bacteria - Fecal Coliform	200 organisms/100 ml		geometric mean of ≥ 5 samples taken within 30 da		1976 STD
	<② 10% of samples of > 400 organisms /100 ml.		samples taken within 30 da		
Fecal Coliform to Fecal Streptococcus Ratio (FC/FS)		> 4.0	indicates human contamination		
		< 0.7	indicates other animal contamination		
		0.7 - 4.0	indicates combination of both human and other animal contamination		
Beryllium	11 µg/l				1976 STD
	1100 µg/l				1976 STD
	100 µg/l		toxicity	continuous agricultural irrigation	1976 STD
	500 µg/l		toxicity	alkaline, fine-textured soils	1976 STD
BOD_5		5.0 mg/l	warrants attention to O_2 sag problems		MDNR-1
Boron	750 µg/l		toxicity	long-term agricultural irrigation	1976 STD
Cadmium	0.4 µg/l		toxicity to coldwater fish	soft waters[2]	1976 STD
	4.0 µg/l		toxicity to warmwater fish	soft waters[2]	1976 STD
	1.2 µg/l		toxicity to coldwater fish	hard waters[2]	1976 STD
	12.0 µg/l		toxicity to warmwater fish	hard waters	1976 STD

PARAMETER	STANDARD	GUIDELINE	NOTE/CRITERIA	APPLICABILITY	SOURCE¹
Chloride		125 mg/l 50 mg/l	public water supply public water supply	point of intake Great Lakes point of intake	MDNR-1 1976 STD
Chlorophyll-a		>10 mg/l	potentially shows signs of eutrophication^3	Lakes	MDNR-2, WQC 1972
		< 4 mg/l	potentially oligotrophic^3	Lakes	WQC 1972
Chromium-Total	100 µg/l		toxicity to aquatic life		1976 STD
		50 mg/l	toxicity to aquatic life		WQC 1972
Chromium-Hexavalent	25 µg/l		toxicity to aquatic life		1976 STD
Copper		1.0 mg/l	public water supplies		QCW 1976
Cyanide	5 µg/l		toxicity to aquatic life		1976 STD
Iron-Filtrable	300 µg/l			Great Lakes	1976 STD
Iron-Total		300 µg/l 1.0 mg/l	public water supply protection of aquatic life		QCW 1976 QCW 1976
Lead	30 µg/l		public water supply		1976 STD
Mercury	0.01 µg/l		toxicity to aquatic life		1976 STD
Nickel	0.01 of 96 Hr LC_{50}		toxicity to aquatic life		1976 STD
Nitrogen-Ammonia (NH_3)		0.4 mg/l 0.02 mg/l	toxicity to aquatic life un-ionized form		MDNR-1 WQC 1972
(NO_3) -Nitrate	10 mg/l 2 mg/l		public water supply		DWS 1962 MDNR-1

PARAMETER	STANDARD	GUIDELINE	NOTE/CRITERIA	APPLICABILITY	SOURCE
Nitrogen (Total Inorganic) ($NH_3 + NO_2 + NO_3$)		> 0.3 mg/l	potentially shows signs of eutrophication[3]	Lakes	MDNR-2
Nitrogen (Total Organic)		> 0.8 mg/l	potentially shows signs of eutrophication[3]	Lakes	MDNR-2
Oxygen-Dissolved	5.0 mg/l		protection of warmwater species	minimum, except in mixing zones	1976 STD
	7.0 mg/l		protection of coldwater species	Great Lakes -connecting waters, coldwater inland lakes, trout streams- MDNR 1976 list	
	see 1976 STD	clinograde curve 0.5 mg/l at 1 meter off of bottom	potentially shows signs of eutrophication[3]	inland lakes lakes	1976 STD MDNR-2
Pesticides			see Quality Criteria for Water 1976		
pH	6.7 - 8.5		range	Great Lakes & connecting waters	1976 STD
	6.5 - 8.8		range	all other waters	1976 STD
Phenol		1 µg/l	protect aquatic life, prevent fish tainting		QCW 1976
Phosphorus-Total		> 0.5 mg/l	suggests enrichment problem	streams and lakes	MDNR-1
		0.1 mg/l		streams	QCW 1976
		0.05 mg/l		streams influent to a lake	QCW 1976
		0.025 mg/l	volume-averaged concentration for a lake	lake	QCW 1976
		> 0.1 mg/l	potentially shows signs of eutrophication[3]	lake	MDNR-2

PARAMETER	STANDARD	GUIDELINE	NOTE/CRITERIA	APPLICABILITY	SOUR
PCBs	< 0.001 $\overset{\mu}{m}$g/l		toxicity to aquatic and human life		1976 STD
Secchi Depth		< 2 m	potentially shows signs of eutrophication[3]	Lakes	MDNR-2
		> 4.6 m	potentially oligotrophic[3]	Lakes	MDNR-2
Selenium	0.01 of 96 Hr LC_{50}		toxicity to aquatic and human life		1976 STD
Silver	0.01 of 96 Hr LC_{50}		toxicity to aquatic and human life		1976 STD
Solids-Suspended (Non-Filterable Residue)		25 mg/l	protection of aquatic life		MDNR-1
Solids-Tot. Dissolved (Filterable Residue)	200 mg/l 500 mg/l 750 mg/l		 monthly average single value	Lake Erie that which is due to controllable point sources	1976 STD 1976 STD 1976 STD
Sulfide	2 mg/l		undissociated H_2S		1976 STD
Temperature	see 1976 STD				1976 STD
Turbidity	5 turbidity units		public water supply		DWS 196
Zinc	0.01 of 96 Hr LC_{50}		toxicity to aquatic life		1976 ST

FOOTNOTES

1. Several sources have been used to assemble these standards and guidelines:

   (a) DWS 1962: Drinking Water Standards, U.S. Public Health Service, 1962.

   (b) MDNR-1: These are the "Staff Precautionary Limits" used informally by Michigan Department of Natural Resources staff in assessing water quality. Values in excess of these limits may indicate water quality problems. These are not standards, they do not have the force of law. Moreover, there may be local, natural conditions which exceed these values. They are meant to assist in interpretation of water quality data.

   (c) MDNR-2: These are signs of potential eutrophication of lakes, as used by the Inland Lakes Management Unit, Michigan Department of Natural Resources. See Water Quality and Pollution Control in Michigan, Michigan Department of Natural Resources, Bureau of Water Management, April, 1976. Table 1, page 28. A single parameter is not sufficient to indicate the presence/absence of eutrophication; rather several such parameters must be assessed jointly.

   (d) QCW 1976: Quality Criteria for Water, 1976. U.S. EPA, Washington, D.C. 1977. NTIS PB-263-943.

   (e) WQC 1972: Water Quality Criteria, 1972. U.S. EPA, Washington, D.C. March, 1973. EPA-R3-73.033

   (f) 1976 STD: State of Michigan proposed Water Quality Standards, 1976. April, 1977 Draft.

2. Soft Waters: $< 100\ mgl^{-1}\ CaCO_3$

   Hard Waters: $> 100\ mgl^{-1}\ CaCO_3$

3. Potentially shows signs of eutrophication per guidelines of Inland Lake Management Unit, Michigan Department of Natural Resources. See note following 1(c) above.

APPENDIX III

APP - III

STATION NUMBER 04174500

DURATION TABLE OF DAILY VALUES FOR YEAR ENDING SEPTEMBER 30

DISCHARGE, IN CUBIC FEET PER SECOND
MEAN
HURON RIVER AT ANN ARBOR, MICH.

NUMBER OF DAYS IN CLASS

CLASS YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1915																			2	29	56	96	76	37	21	22	9	9	6	2					
1916									1			1	1			1	15	18	22	11	28	26	26	50	36	50	26	32	6	4	4	2	6		
1917																1	15	24	32	52	53	46	32	19	21	41	22	5	2						
1918									3			2	4	4	13	25	28	48	51	31	29	20	23	24	3	8	5	7	5	12	10	4	5		1
1919									1	1				2		5	27	39	33	42	60	29	21	18	14	19	17	12	7	13	3	2			
1920									1			2		3	2	1	30	46	57	66	31	21	24	23	19	13	10	5	3	5	4				
1921													1	1	5	1	32	36	37	57	34	31	35	34	19	29	12	1							
1922			1			1						1		2	2	1	26	38	27	18	52	25	21	27	31	37	28	8	9	6	1	2	1		
1923			8								1	1	4	1	10	11	29	53	107	46	20	11	11	23	5	14	8	2							
1924			4									1		1	8	4	33	56	36	35	27	41	39	28	16	17	16	2	1	1					
1925			5				1			2		2	6	5	27	22	93	59	35	24	20	22	13	14	6	4	5								
1926											1					3	23	19	24	24	59	47	33	32	27	23	16	5	3	18	6	2			
1927														2	4	16	18	9	25	37	42	54	59	37	32	26	4								
1928													1	1		2	14	39	32	52	33	24	25	48	45	35	15								
1929													1	3	2	11	41	19	35	46	63	28	11	9	8	12	21	42	11	2					
1930												1	2	14	26	15	33	6	22	12	27	21	38	44	38	21	15	14	11	5					
1931		2								2	8	21	16	16	15	11	15	55	79	64	37	13	11												
1932													1	3	30	22	32	41	33	41	39	37	29	41	13	2	2								
1933													1	4	17	22	35	22	29	26	42	24	19	52	25	22	15	10							
1934			20					5	4	2	24	16	6	21	10	10	31	46	53	62	21	3	4	4	5	4	4	4	4	1	1				
1935													3	10	19	41	65	51	18	36	32	25	17	22	14	10	1	1							
1936			6				1	6	5	1	12	7	10	15	19	26	35	30	36	40	31	16	13	16	21	15	5								
1937															2	2	8	37	40	31	53	36	39	45	23	20	10	13	4	2					
1938															3	8	36	54	53	44	23	14	20	21	18	19	14	23	12	3					
1939												1	5	11	25	32	56	26	34	32	37	17	7	11	20	12	16	13	6	4					
1940														4	20	12	37	88	58	19	29	51	18	6	4	8	5	7							
1941								1				2	10	25	30	10	10	7	27	56	46	31	41	41	15	12	1								
1942									1		1		1	2	2	4	30	68	55	46	35	40	18	9	8	14	10	8	10	3					
1943																	3	6	22	28	45	47	38	36	31	27	20	18	15	4	12	11	2		
1944										1		7	3	10	18	23	14	16	39	33	29	45	13	17	36	37	18	7							
1945															2	5	37	82	68	17	22	15	27	37	15	9	7	7	7	4	3	1			
1946										2			3	14	32	19	11	2	24	30	75	40	29	28	23	16	6	10	1						
1947			1				3					2		3	4	7	7	26	40	42	41	26	19	22	27	20	19	23	8	11	3	2	2	7	
1949													1	1		1	9	36	38	37	21	35	50	43	25	26	14	10	4	11	2	1			
1950																	4	7	25	48	23	34	21	19	31	24	37	34	22	17	5	9	5		
1951																		1	7	54	25	31	23	15	42	42	47	44	19	12	3				
1952																	1	19	60	29	5	13	19	38	58	38	24	41	16	5					
1953										1					1	6	23	29	34	33	25	53	55	45	45	14	1								
1954									2	3			1	1	5	4	50	27	49	65	21	13	13	13	22	30	26	18	1	1					
1955															4	9	26	27	19	18	25	27	34	33	58	34	23	23	4	1					

STATION NUMBER 04174500

DURATION TABLE OF DAILY VALUES FOR YEAR ENDING SEPTEMBER 30

DISCHARGE, IN CUBIC FEET PER SECOND
MEAN
HURON RIVER AT ANN ARBOR, MICH.

NUMBER OF DAYS IN CLASS

CLASS YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1956															2		2	6	28	86	37	32	40	36	18	21	10	11	12	13	12				
1957																		10	44	52	31	60	62	42	41	21	2								
1958																7	36	51	41	38	15	41	65	36	21	9	5								
1959													3	1	9	5	32	55	33	54	35	17	29	19	13	12	14	22	9	3					
1960																2	13	18	33	16	8	33	58	71	48	25	22	9	10						
1961														1		1	20	62	63	43	38	34	42	16	16	10	10	4	3	2					
1962												1		4	2	7	29	17	49	59	65	50	28	19	11	4	3	7	5	3	2				
1963														4	26	26	30	35	51	55	38	39	24	16	6	7	8								
1964													2	21	43	17	51	45	69	36	28	23	23	8											
1965												3	13	15	22	24	56	27	42	28	32	13	14	18	17	16	13	8	3	1					
1966														1	17	25	44	36	35	34	40	44	26	34	19	7	2	1							
1967															12	17	41	23	25	22	44	48	43	36	17	8	14	13	1	1					
1968																	2	4	8	8	9	51	79	61	44	39	13	19	9	10	5	2	3		
1969																	4	11	20	6	13	40	39	49	42	44	42	33	18	3	1				
1970														1	4	5	15	8	17	22	66	85	36	32	27	20	16	11							
1971										1	3	16	5	12	36	5	14	13	16	20	30	24	38	52	31	13	16	10	6	2	2				
1972									1		1			1	1	4	13	25	50	74	57	46	25	21	14	25	7	1							
1973														2	3	1	2	6	17	10	20	21	29	62	68	49	30	14	22	9					
1974															2	2	8	5	30	36	16	18	25	30	37	30	31	27	26	23	13	3	3		
1975														1		1	3	16	27	21	22	48	68	34	36	25	25	22	10	4	2				
1976																2	22	18	23	15	16	17	29	72	28	30	21	30	12	13	10	7	1		
1977														1		4	35	19	69	87	39	26	13	17	14	22	8	11							
1978												7	4	4	8	11	31	17	22	30	49	68	34	18	20	12	5	9	10	5	1				
1979														1	1	12	26	17	30	60	55	53	26	15	27	19	14	7	2						
1980															1	2	4	14	26	40	39	37	50	52	36	23	17	20	5						

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                                        STATION NUMBER  04174500
                              DURATION TABLE OF DAILY VALUES FOR YEAR ENDING SEPTEMBER 30
DISCHARGE, IN CUBIC FEET PER SECOND
MEAN
HURON RIVER AT ANN ARBOR, MICH.

CLASS   VALUE   TOTAL   ACCUM   PERCT       CLASS   VALUE   TOTAL   ACCUM   PERCT       CLASS   VALUE   TOTAL   ACCUM   PERCT
  0       0.0       0   23741   100.0         12     44.0     108   23496    99.0         24    590.0    1571    5325    22.4
  1       4.0       2   23741   100.0         13     54.0     249   23388    98.5         25    730.0    1317    3754    15.8
  2       5.0      45   23739   100.0         14     67.0     546   23139    97.5         26    910.0     902    2437    10.2
  3       6.2       0   23694    99.8         15     84.0     573   22593    95.2         27   1100.0     747    1535     6.4
  4       7.7       0   23694    99.8         16    100.0    1565   22020    92.8         28   1400.0     360     788     3.3
  5       9.5       1   23694    99.8         17    130.0    1870   20455    86.2         29   1700.0     239     428     1.8
  6      12.0       5   23693    99.8         18    160.0    2385   18585    78.3         30   2200.0     105     189      .7
  7      15.0      12   23688    99.8         19    200.0    2465   16200    68.2         31   2700.0      48      84      .3
  8      18.0      19   23676    99.7         20    250.0    2258   13735    57.9         32   3300.0      28      36      .1
  9      23.0      16   23657    99.6         21    310.0    2196   11477    48.3         33   4200.0       7       8
 10      28.0      51   23641    99.6         22    380.0    2009    9281    39.1         34   5200.0       1       1
 11      35.0      94   23590    99.4         23    470.0    1947    7272    30.6

VALUE EXCEEDED 'P' PERCENT OF TIME

V95 =      85.0
V90 =     110.0
V75 =     170.0
V70 =     190.0
V50 =     300.0
V25 =     550.0
V10 =     920.0
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STATION NUMBER 04174500

HIGHEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

HURON RIVER AT ANN ARBOR, MICH.

YEAR	1	3	7	15	30	60	90	120	183	ANNUAL
1915	2050.0 23	1750.0 27	1530.0 28	1500.0 21	1200.0 24	881.0 29	723.0 34	632.0 34	549.0 32	474.0 10
1916	3950.0 5	3560.0 [illegible]	3510.0 3	2830.0 5	2030.0 7	1820.0 5	1310.0 6	1170.0 4	1040.0 4	680.0 4
1917	1670.0 36	1550.0 32	1320.0 33	1130.0 35	1030.0 33	907.0 28	812.0 26	761.0 23	609.0 25	421.0 24
1918	5840.0 1	4530.0 2	3880.0 2	2840.0 3	2630.0 3	1910.0 3	1440.0 4	1150.0 5	823.0 11	497.0 15
1919	3090.0 8	2820.0 8	2430.0 9	1940.0 11	1630.0 10	1410.0 7	1140.0 10	937.0 14	750.0 15	476.0 17
1920	2490.0 16	2350.0 13	2090.0 14	1840.0 14	1350.0 15	1060.0 19	837.0 24	692.0 29	538.0 34	372.0 33
1921	1140.0 45	1060.0 44	990.0 43	896.0 46	850.0 41	790.0 38	640.0 41	540.0 44	504.0 39	350.0 37
1922	3360.0 7	2980.0 7	2450.0 8	2000.0 9	1640.0 9	1240.0 10	1070.0 13	904.0 16	799.0 13	517.0 13
1923	1230.0 42	1150.0 42	1040.0 42	953.0 42	836.0 43	652.0 46	549.0 47	460.0 50	368.0 51	255.0 51
1924	1750.0 32	1530.0 34	1200.0 37	1010.0 40	934.0 37	827.0 36	708.0 35	625.0 37	509.0 38	343.0 42
1925	1040.0 48	937.0 51	820.0 53	478.0 55	607.0 54	506.0 54	433.0 56	364.0 56	290.0 56	200.0 56
1926	2950.0 10	2730.0 9	2390.0 10	2190.0 8	2080.0 5	1440.0 6	1150.0 8	958.0 11	810.0 12	542.0 11
1927	927.0 55	899.0 53	852.0 52	823.0 49	724.0 47	697.0 42	611.0 43	552.0 43	487.0 43	380.0 31
1928	942.0 53	939.0 50	918.0 48	891.0 46	820.0 44	716.0 41	672.0 40	627.0 35	596.0 26	498.0 26
1929	1930.0 26	1700.0 28	1510.0 29	1370.0 26	1270.0 20	1160.0 16	1140.0 9	956.0 12	742.0 18	465.0 20
1930	1820.0 29	1770.0 25	1700.0 21	1510.0 20	1150.0 26	1030.0 20	932.0 20	899.0 17	745.0 17	468.0 19
1931	467.0 58	450.0 58	433.0 58	396.0 58	346.0 58	290.0 58	273.0 58	266.0 58	235.0 58	171.0 58
1932	957.0 52	879.0 54	725.0 56	613.0 56	553.0 56	466.0 56	447.0 55	435.0 53	400.0 49	270.0 49
1933	1300.0 38	1240.0 38	1170.0 38	1090.0 36	898.0 39	844.0 32	741.0 33	664.0 30	594.0 27	379.0 32
1934	2590.0 14	2110.0 17	1770.0 16	1370.0 27	990.0 35	620.0 48	466.0 53	396.0 55	334.0 55	206.0 55
1935	1160.0 43	944.0 49	873.0 50	801.0 50	609.0 49	510.0 53	470.0 52	443.0 51	362.0 53	237.0 54
1936	1040.0 49	960.0 48	934.0 47	897.0 44	796.0 48	680.0 43	563.0 46	461.0 49	387.0 50	244.0 53
1937	1960.0 25	1630.0 30	1450.0 30	1290.0 30	1050.0 31	855.0 30	825.0 25	734.0 26	611.0 24	423.0 22
1938	2140.0 19	1960.0 19	1730.0 18	1520.0 19	1310.0 17	1180.0 14	1020.0 16	872.0 18	686.0 20	427.0 21
1939	1920.0 27	1800.0 24	1690.0 22	1410.0 24	1070.0 29	970.0 25	896.0 21	742.0 25	571.0 29	345.0 40
1940	1280.0 40	1230.0 39	1150.0 39	1050.0 38	845.0 42	664.0 50	510.0 49	464.0 48	363.0 52	254.0 52
1941	922.0 56	861.0 55	804.0 54	609.0 56	510.0 53	526.0 52	457.0 54	470.0 47	436.0 47	293.0 47
1942	2090.0 21	1830.0 22	1610.0 24	1560.0 18	1250.0 21	972.0 24	761.0 30	668.0 32	530.0 36	349.0 39
1943	3450.0 6	3180.0 6	2900.0 6	2835.0 4	2850.0 1	1750.0 4	1460.0 3	1350.0 3	1130.0 2	717.0 3
1944	1300.0 39	1190.0 40	1120.0 41	1050.0 39	935.0 36	849.0 31	808.0 27	712.0 28	563.0 30	382.0 30
1945	2890.0 11	2600.0 11	2260.0 11	1870.0 12	1470.0 13	1010.0 22	853.0 23	759.0 24	589.0 28	371.0 34
1946	1410.0 37	1380.0 37	1310.0 34	1200.0 33	997.0 34	703.0 40	678.0 39	592.0 39	497.0 41	[illegible] 38
1947	6170.0 2	4900.0 1	4600.0 1	3540.0 1	2680.0 2	1930.0 2	1630.0 2	1360.0 2	1010.0 9	633.0 9
1949	3050.0 9	2430.0 12	2110.0 13	1840.0 13	1340.0 16	1150.0 17	1010.0 17	925.0 15	758.0 14	493.0 16
1950	4170.0 3	3940.0 3	3410.0 4	3170.0 2	2470.0 4	1990.0 1	1720.0 1	1590.0 1	1320.0 1	812.0 1
1951	2330.0 17	2270.0 15	2120.0 12	1960.0 10	1650.0 8	1390.0 8	1260.0 7	1160.0 6	1110.0 3	748.0 2
1952	2090.0 22	1870.0 20	1640.0 23	1450.0 22	1350.0 14	1210.0 13	1130.0 11	1090.0 8	937.0 6	635.0 8
1953	928.0 54	835.0 56	775.0 55	730.0 52	683.0 50	664.0 45	616.0 42	589.0 42	514.0 37	367.0 36

APP III - 4

STATION NUMBER 04174500

HIGHEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

HURON RIVER AT ANN ARBOR, MICH.

YEAR	1	3	7	15	30	60	90	120	183	ANNUAL
1954	1740.0 33	1530.0 35	1350.0 32	1200.0 34	1050.0 32	982.0 23	944.0 19	799.0 20	641.0 22	402.0 28
1955	1820.0 30	1660.0 31	1400.0 31	1220.0 31	1110.0 27	924.0 26	868.0 28	780.0 22	749.0 16	514.0 14
1956	2690.0 12	2650.0 10	2610.0 7	2320.0 7	2040.0 6	1390.0 9	1300.0 6	1130.0 7	860.0 10	565.0 10
1957	1030.0 50	934.0 52	861.0 51	775.0 51	647.0 52	627.0 47	600.0 45	569.0 41	534.0 35	395.0 29
1958	1090.0 47	993.0 46	936.0 46	883.0 47	683.0 51	612.0 49	547.0 48	497.0 46	472.0 44	324.0 45
1959	2110.0 20	1870.0 21	1590.0 26	1440.0 23	1200.0 18	1150.0 18	906.0 18	840.0 19	625.0 23	404.0 27
1960	1680.0 35	1660.0 29	1600.0 25	1400.0 25	1200.0 25	920.0 27	808.0 29	797.0 21	716.0 19	520.0 12
1961	2030.0 24	1820.0 23	1580.0 27	1310.0 29	1060.0 30	777.0 39	690.0 37	607.0 38	458.0 46	338.0 43
1962	2500.0 15	2200.0 16	1760.0 17	1600.0 16	1220.0 22	839.0 34	678.0 38	584.0 40	496.0 42	344.0 41
1963	1000.0 51	963.0 47	940.0 45	898.0 43	723.0 48	547.0 51	485.0 50	438.0 52	343.0 54	258.0 50
1964	524.0 57	503.0 57	463.0 57	448.0 57	399.0 57	382.0 57	334.0 57	301.0 57	259.0 57	186.0 57
1965	1820.0 31	1540.0 33	1290.0 36	1080.0 37	894.0 40	838.0 35	756.0 31	642.0 33	500.0 46	306.0 46
1966	1150.0 44	1090.0 43	890.0 49	721.0 53	588.0 55	502.0 55	477.0 51	431.0 54	423.0 48	284.0 48
1967	1710.0 34	1480.0 36	1300.0 35	1210.0 32	1080.0 28	841.0 33	695.0 36	627.0 36	540.0 33	371.0 35
1968	4010.0 4	3600.0 4	3160.0 5	2380.0 6	1590.0 11	1230.0 11	1040.0 15	947.0 13	897.0 9	678.0 5
1969	2200.0 18	2010.0 18	1710.0 19	1340.0 28	1200.0 23	1160.0 15	1090.0 12	979.0 10	909.0 8	678.0 6
1970	1240.0 41	1180.0 41	1130.0 40	981.0 41	899.0 38	808.0 37	741.0 32	660.0 31	551.0 31	421.0 23
1971	2590.0 13	2290.0 14	1870.0 15	1560.0 17	1270.0 19	1030.0 21	856.0 22	719.0 27	657.0 21	418.0 25
1972	1120.0 46	1040.0 45	961.0 44	854.0 48	739.0 46	679.0 44	686.0 44	515.0 45	460.0 45	333.0 44
1973	1830.0 28	1750.0 26	1710.0 20	1630.0 15	1510.0 12	1210.0 12	1060.0 14	999.0 9	915.0 7	675.0 7

STATION NUMBER 04174500

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

DISCHARGE, IN CUBIC FEET PER SECOND

MEAN

HURON RIVER AT ANN ARBOR, MICH.

YEAR	1	3	7	14	30	60	90	120	183
1915	133.00 59	165.00 61	188.00 62	199.00 62	205.00 61	286.00 62	300.00 61	306.00 59	308.00 55
1916	193.00 64	215.00 63	229.00 63	269.00 63	325.00 63	346.00 63	367.00 63	366.00 63	448.00 61
1917	22.00 16	81.00 33	108.00 42	120.00 45	129.00 43	143.00 39	164.00 40	185.00 39	222.00 36
1918	85.00 51	117.00 53	126.00 49	127.00 47	131.00 46	171.00 49	181.00 46	225.00 50	215.00 34
1919	18.00 10	42.00 13	54.00 10	69.00 15	73.00 12	84.00 13	97.00 13	106.00 13	141.00 17
1920	18.00 11	68.00 24	106.00 41	119.00 43	130.00 44	144.00 40	161.00 39	180.00 37	234.00 41
1921	20.00 13	82.00 34	99.00 37	104.00 32	112.00 29	123.00 26	128.00 23	132.00 22	170.00 23
1922	66.00 42	108.00 48	117.00 46	120.00 44	127.00 41	160.00 47	182.00 47	218.00 48	253.00 46
1923	6.00 5	69.00 25	103.00 38	106.00 33	113.00 32	123.00 27	135.00 25	143.00 23	156.00 21
1924	6.00 6	27.00 5	57.00 11	63.00 12	73.00 13	94.00 16	105.00 17	119.00 20	135.00 14
1925	6.00 7	36.00 9	79.00 21	94.00 26	107.00 26	114.00 22	119.00 21	118.00 17	129.00 9
1926	6.00 8	30.00 6	44.00 7	47.00 6	57.00 5	75.00 8	88.00 10	99.00 9	153.00 19
1927	32.00 19	86.00 40	97.00 33	108.00 35	118.00 34	147.00 43	165.00 41	199.00 43	270.00 48
1928	55.00 32	79.00 32	86.00 25	90.00 22	98.00 21	124.00 29	153.00 34	165.00 31	223.00 37
1929	53.00 29	104.00 47	113.00 44	118.00 42	125.00 40	135.00 36	149.00 32	167.00 33	195.00 29
1930	44.00 25	64.00 20	92.00 29	92.00 23	101.00 24	107.00 20	119.00 22	165.00 32	233.00 40
1931	37.00 20	53.00 16	57.00 12	61.00 11	67.00 9	76.00 10	98.00 14	111.00 14	132.00 10
1932	4.00 1	23.00 4	34.00 3	36.00 4	40.00 3	45.00 3	53.00 3	61.00 2	92.00 2
1933	73.00 47	76.00 29	79.00 22	86.00 21	99.00 22	110.00 21	137.00 28	152.00 27	191.00 27
1934	53.00 30	65.00 21	70.00 20	73.00 19	81.00 18	93.00 15	103.00 16	113.00 16	135.00 15
1935	6.00 2	9.30 1	13.00 1	16.00 1	18.00 1	24.00 1	32.00 1	42.00 1	59.00 1
1936	63.00 38	84.00 37	88.00 26	92.00 24	94.00 20	102.00 19	112.00 19	119.00 18	167.00 22
1937	6.00 3	16.00 2	17.00 2	19.00 2	27.00 2	40.00 2	53.00 2	74.00 3	118.00 6
1938	73.00 48	119.00 54	124.00 48	133.00 49	139.00 48	156.00 45	170.00 43	189.00 40	223.00 38
1939	71.00 45	82.00 35	91.00 28	99.00 28	112.00 30	115.00 23	118.00 20	119.00 19	134.00 12
1940	39.00 21	62.00 19	68.00 17	71.00 16	74.00 15	80.00 12	86.00 8	104.00 12	117.00 4
1941	57.00 34	66.00 22	69.00 18	72.00 17	79.00 17	136.00 37	154.00 35	168.00 34	207.00 32
1942	15.00 9	45.00 14	53.00 9	55.00 9	65.00 8	69.00 5	72.00 5	91.00 5	136.00 16
1943	19.00 12	96.00 45	106.00 39	114.00 40	128.00 42	136.00 38	136.00 27	151.00 26	208.00 33
1944	108.00 56	154.00 59	156.00 58	161.00 56	173.00 57	217.00 60	249.00 57	276.00 55	274.00 51
1945	24.00 17	36.00 10	43.00 5	50.00 8	60.00 6	75.00 9	87.00 9	95.00 6	117.00 5
1946	102.00 55	128.00 55	132.00 52	134.00 50	146.00 50	164.00 48	216.00 52	264.00 53	273.00 50
1947	6.00 4	35.00 8	61.00 14	66.00 13	69.00 10	73.00 6	80.00 6	103.00 11	135.00 13
1950	44.00 26	83.00 36	117.00 45	131.00 48	139.00 49	158.00 46	182.00 48	206.00 45	228.00 39
1951	116.00 58	132.00 57	144.00 56	156.00 55	174.00 58	206.00 56	270.00 59	315.00 60	407.00 60
1952	144.00 60	179.00 62	184.00 61	195.00 61	212.00 62	214.00 58	263.00 58	290.00 56	388.00 58
1953	82.00 49	131.00 56	149.00 57	162.00 57	164.00 52	176.00 51	177.00 45	184.00 38	237.00 42
1954	22.00 14	23.00 3	82.00 23	111.00 38	120.00 37	125.00 30	135.00 26	149.00 25	171.00 24
1955	70.00 44	78.00 30	93.00 30	108.00 36	118.00 35	123.00 28	150.00 37	243.00 51	390.00 59

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                                        STATION NUMBER  04174500
              LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31
DISCHARGE, IN CUBIC FEET PER SECOND
MEAN
HURON RIVER AT ANN ARROR, MICH.

YEAR        1           3           7          14          30          60          90         120         183
1956     69.00 43    85.00 38    89.00 27    94.00 25   103.00 25   120.00 25   140.00 29   156.00 29   206.00 31
1957    155.00 62   162.00 60   162.00 59   165.00 59   170.00 55   184.00 52   219.00 53   253.00 52   282.00 53
1958    146.00 61   148.00 58   162.00 60   172.00 60   196.00 60   211.00 57   231.00 55   298.00 58   365.00 57
1959     84.00 50    93.00 44    98.00 34   101.00 29   119.00 36   128.00 33   134.00 24   147.00 24   155.00 20
1960     48.00 27    49.00 15    61.00 15    73.00 10   100.00 23   119.00 24   145.00 30   155.00 28   243.00 43

1961     90.00 53   111.00 49   112.00 43   116.00 41   131.00 45   145.00 42   161.00 38   176.00 36   183.00 26
1962     63.00 39   113.00 50   119.00 47   125.00 46   136.00 47   151.00 44   209.00 51   221.00 49   256.00 47
1963     40.00 22    72.00 27    86.00 24   101.00 30   115.00 33   127.00 31   149.00 33   159.00 30   192.00 28
1964     57.00 35    59.00 18    66.00 16    68.00 14    73.00 14    78.00 11    81.00  7    87.00  4   109.00  3
1965     50.00 28    54.00 17    57.00 13    61.00 10    75.00 16    95.00 17    96.00 12    99.00 10   128.00  7

1966     42.00 24    42.00 11    44.00  6    47.00  5    60.00  7    75.00  7    93.00 11    97.00  8   133.00 11
1967     63.00 40    67.00 23    70.00 19    77.00 20    88.00 19   100.00 18   100.00 15   111.00 15   147.00 18
1968     72.00 46    87.00 41    93.00 31   101.00 31   112.00 31   127.00 32   148.00 31   195.00 41   250.00 45
1969    168.00 63   294.00 64   305.00 64   322.00 64   328.00 64   349.00 64   376.00 64   442.00 64   538.00 64
1970    111.00 57   116.00 52   134.00 54   162.00 58   167.00 54   202.00 55   238.00 56   294.00 57   307.00 54

1971     60.00 36    78.00 31    98.00 35   109.00 37   123.00 38   172.00 50   226.00 54   270.00 54   342.00 56
1972     25.00 18    31.00  7    35.00  4    36.00  3    42.00  4    57.00  4    71.00  4    96.00  7   128.00  8
1973     22.00 15    69.00 26   130.00 50   155.00 54   171.00 56   193.00 54   200.00 49   217.00 47   280.00 52
1974     62.00 37    74.00 28   133.00 53   150.00 53   194.00 59   258.00 61   309.00 62   352.00 61   453.00 63
1975    101.00 54   114.00 51   135.00 55   145.00 52   164.00 53   199.00 53   201.00 50   212.00 46   271.00 49

1976     56.00 33    88.00 43   132.00 51   140.00 51   158.00 51   217.00 59   278.00 60   355.00 62   449.00 62
1977     88.00 52   101.00 46   106.00 40   112.00 39   125.00 39   144.00 41   172.00 44   197.00 42   216.00 35
1978     64.00 41    87.00 42    99.00 36   106.00 34   111.00 28   132.00 34   156.00 36   173.00 35   200.00 30
1979     40.00 23    42.00 12    46.00  8    48.00  7    70.00 11    91.00 14   106.00 18   127.00 21   179.00 25
1980     55.00 31    85.00 39    93.00 32    98.00 27   108.00 27   135.00 35   165.00 42   203.00 44   245.00 44
```

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```
HURON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING MARCH 31                    N =     57                    STATION  04174500
    1  DAY LOW FLOW

  INPUT DATA (ZERO VALUES OMITTED)

      133.000      193.000       22.000       85.000       18.000       18.000       20.000       46.000        6.000        6.000
        6.000        6.000       32.000       55.000       53.000       44.000       37.000        4.000       73.000       53.000
        6.000       63.000        6.300       73.000       71.000       39.000       57.000       15.000       19.000      108.000
       24.000      102.000        6.000       44.000      116.000      144.000       82.000       22.000       70.000       69.000
      155.000      146.000       84.000       48.000       90.000       63.000       46.000       57.000       50.000       42.000
       63.000       72.000      168.000      111.000       60.000       25.000       22.000

  MEAN =          58.982

  VARIANCE =          2034.753

  STANDARD DEVIATION =          45.108

  SKEWNESS =          1.015

  STANDARD ERROR OF SKEWNESS =          0.316

  SERIAL CORRELATION COEFFICIENT =          0.316

  COEFFICIENT OF VARIATION =          0.765

  MEAN LOGS =          1.606

  VARIANCE LOGS =          0.190

  STANDARD DEVIATION LOGS =          0.436

  SKEWNESS LOGS =          -0.767

  STANDARD ERROR OF SKEWNESS LOGS =          0.316

  SERIAL CORRELATION COEFFICIENT LOGS =          0.232

  COEFFICIENT OF VARIATION LOGS =          0.272

  NON EXCEED PROB     RECURRENCE INTERVAL     DISCHARGE

        0.0100               100.00             2.261
        0.0500                20.00             6.401
        0.1000                10.00            10.546
        0.2000                 5.00            18.359
        0.5000                 2.00            45.785
        0.8000                 1.25            95.296
        0.9000                 1.11           130.797
        0.9600                 1.04           175.017
        0.9800                 1.02           206.260
        0.9900                 1.01           235.529
        9.9950                 1.01           262.815
```

```
HURON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING MARCH 31                                 N =     57                                   STATION  04174500
   3  DAY LOW FLOW

  INPUT DATA (ZERO VALUES OMITTED)
       165.000     215.000      81.300     117.000      41.700      68.000      82.300     100.000      69.000      27.300
        38.300      30.000      86.300      78.700     104.000      64.300      52.700      23.300      75.700      64.700
         9.330      83.700      16.000     119.000      82.300      62.300      66.000      45.300      96.000     184.000
        35.700     128.000      34.700      82.700     132.000     179.000     131.000      22.700      78.300      84.700
       162.000     148.000      93.300      49.000     111.000     113.000      71.700      59.300      54.300      42.000
        66.700      87.000     294.000     116.000      78.300      31.300      69.000

  MEAN =          85.600
  VARIANCE =          2671.137
  STANDARD DEVIATION =          51.683
  SKEWNESS =          1.522
  STANDARD ERROR OF SKEWNESS =          0.316
  SERIAL CORRELATION COEFFICIENT =          0.226
  COEFFICIENT OF VARIATION =          0.604
  MEAN LOGS =          1.853
  VARIANCE LOGS =          0.079
  STANDARD DEVIATION LOGS =          0.281
  SKEWNESS LOGS =          -0.678
  STANDARD ERROR OF SKEWNESS LOGS =          0.316
  SERIAL CORRELATION COEFFICIENT LOGS =          0.186
  COEFFICIENT OF VARIATION LOGS =          0.152
  NON EXCEED PROB     RECURRENCE INTERVAL     DISCHARGE
        0.0100              100.00              11.595
        0.0500               20.00              22.066
        0.1000               10.00              30.139
        0.2000                5.00              42.736
        0.5000                2.00              76.712
        0.8000                1.25             124.207
        0.9000                1.11             153.779
        0.9600                1.04             187.945
        0.9800                1.02             210.950
        0.9900                1.01             231.962
        0.9950                1.01             251.214
```

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HURON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING MARCH 31                        N =    57                            STATION  04174500
   7  DAY LOW FLOW

INPUT DATA (ZERO VALUES OMITTED)

     100.000     229.000     108.000     126.000      53.700     106.000      99.300     117.000     103.000      57.300
      70.700      43.700      97.400      85.400     113.600      92.000      57.400      34.100      78.700      69.600
      13.300      80.400      16.900     124.000      90.700      67.900      69.400      53.100     106.000     156.000
      43.000     132.000      60.900     117.000     144.000     104.000     149.000      82.100      93.000      89.000
     162.000     162.000      98.400      61.100     112.000     119.000      86.300      66.300      56.600      43.700
      70.300      93.100     305.000     134.000      98.100      35.000     130.000

MEAN =         99.124
VARIANCE =         2622.228
STANDARD DEVIATION =          51.208
SKEWNESS =          1.427
STANDARD ERROR OF SKEWNESS =          0.316
SERIAL CORRELATION COEFFICIENT =          0.258
COEFFICIENT OF VARIATION =          0.517
MEAN LOGS =          1.937
VARIANCE LOGS =          0.060
STANDARD DEVIATION LOGS =          0.244
SKEWNESS LOGS =          -0.912
STANDARD ERROR OF SKEWNESS LOGS =          0.316
SERIAL CORRELATION COEFFICIENT LOGS =          0.139
COEFFICIENT OF VARIATION LOGS =          0.126
NON EXCEED PROB     RECURRENCE INTERVAL     DISCHARGE
      0.0100              100.00              16.358
      0.0500               20.00              30.421
      0.1000               10.00              40.701
      0.2000                5.00              56.216
      0.5000                2.00              94.126
      0.8000                1.25             139.773
      0.9000                1.11             164.572
      0.9600                1.04             190.170
      0.9800                1.02             205.697
      0.9900                1.01             218.726
      0.9950                1.01             229.744
```

```
HURON RIVER AT ANN ARBOR, MICH.                                          N =     57                               STATION  04174500
1915-1973,  12 MON PERIOD ENDING MARCH 31
  14  DAY LOW FLOW

INPUT DATA (ZERO VALUES OMITTED)

      199.000      269.000      120.000      127.000       69.100      119.000      104.000      120.000      106.000       62.700
       94.100       46.900      108.000       90.300      118.000       92.100       61.300       35.600       86.300       72.900
       16.400       92.100       18.800      133.000       99.100       71.400       72.400       55.400      114.000      161.000
       49.600      134.000       66.100      131.000      156.000      195.000      162.000      111.000      108.000       94.100
      165.000      172.000      101.000       73.200      116.000      125.000      101.000       68.400       61.100       47.000
       77.200      101.000      322.000      162.000      109.000       35.000      155.000

MEAN =        107.603

VARIANCE =         3049.625

STANDARD DEVIATION =         55.223

SKEWNESS =         1.430

STANDARD ERROR OF SKEWNESS =         0.316

SERIAL CORRELATION COEFFICIENT =         0.301

COEFFICIENT OF VARIATION =         0.513

MEAN LOGS =         1.974

VARIANCE LOGS =         0.058

STANDARD DEVIATION LOGS =         0.240

SKEWNESS LOGS =         -0.842

STANDARD ERROR OF SKEWNESS LOGS =         0.316

SERIAL CORRELATION COEFFICIENT LOGS =         0.176

COEFFICIENT OF VARIATION LOGS =         0.122

NON EXCEED PROB     RECURRENCE INTERVAL     DISCHARGE

      0.0100                  100.00           18.781
      0.0500                   20.00           33.952
      0.1000                   10.00           44.999
      0.2000                    5.00           61.389
      0.5000                    2.00          101.717
      0.8000                    1.25          151.111
      0.9000                    1.11          178.601
      0.9600                    1.04          207.666
      0.9800                    1.02          225.735
      0.9900                    1.01          241.218
      0.9950                    1.01          254.509
```

```
HURON RIVER AT ANN ARBOR, MICH.                                   N =     57                            STATION  04174500
1915-1973,  12 MON PERIOD ENDING MARCH 31
  30  DAY LOW FLOW

 INPUT DATA (ZERO VALUES OMITTED)

       205.000     325.000     129.000     131.000      73.300     130.000     112.000     127.000     113.000      73.000
       107.000      56.800     118.000      97.700     125.000     101.000      66.800      40.000      99.100      80.600
        16.400      94.300      27.000     139.600     112.000      73.600      78.900      64.900     128.000     173.000
        60.100     146.000      68.800     139.000     174.000     212.000     164.000     120.000     118.000     103.000
       170.000     196.000     119.000      99.700     131.000     136.000     115.000      73.300      75.200      60.200
        88.300     112.000     328.000     167.000     123.000      42.100     171.000

 MEAN =        118.089

 VARIANCE =          3444.706

 STANDARD DEVIATION =          58.692

 SKEWNESS =          1.524

 STANDARD ERROR OF SKEWNESS =          0.316

 SERIAL CORRELATION COEFFICIENT =          0.297

 COEFFICIENT OF VARIATION =          0.497

 MEAN LOGS =        2.020

 VARIANCE LOGS =          0.051

 STANDARD DEVIATION LOGS =          0.226

 SKEWNESS LOGS =        -0.765

 STANDARD ERROR OF SKEWNESS LOGS =          0.316

 SERIAL CORRELATION COEFFICIENT LOGS =          0.202

 COEFFICIENT OF VARIATION LOGS =          0.112

 NON EXCEED PROB    RECURRENCE INTERVAL    DISCHARGE

       0.0100             100.00              23.594
       0.0500              20.00              40.414
       0.1000              10.00              52.320
       0.2000               5.00              69.695
       0.5000               2.00             111.819
       0.8000               1.25             163.405
       0.9000               1.11             192.512
       0.9600               1.04             223.848
       0.9800               1.02             243.725
       0.9900               1.01             261.070
       0.9950               1.01             276.329
```

```
HURON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING MARCH 31                         N =     57                              STATION  04174500
  60  DAY LOW FLOW
INPUT DATA (ZERO VALUES OMITTED)
      286.000     346.000     143.000     171.000      83.800     144.000     123.000     160.000     123.000      93.800
      114.000      75.100     147.000     124.000     135.000     107.000      75.600      45.000     110.000      93.400
       23.700     102.000      40.300     156.000     115.000      79.900     136.000      69.100     136.000     217.000
       75.300     164.000      73.200     158.000     206.000     214.000     176.000     125.000     123.000     120.000
      104.000     211.000     128.000     119.000     145.000     151.000     127.000      78.200      94.900      75.200
       99.700     127.000     349.000     202.000     172.000      57.400     193.000
MEAN =        135.484
VARIANCE =        4147.852
STANDARD DEVIATION =        64.404
SKEWNESS =        1.341
STANDARD ERROR OF SKEWNESS =        0.316
SERIAL CORRELATION COEFFICIENT =        0.325
COEFFICIENT OF VARIATION =        0.475
MEAN LOGS =        2.084
VARIANCE LOGS =        0.045
STANDARD DEVIATION LOGS =        0.213
SKEWNESS LOGS =        -0.017
STANDARD ERROR OF SKEWNESS LOGS =        0.316
SERIAL CORRELATION COEFFICIENT LOGS =        0.213
COEFFICIENT OF VARIATION LOGS =        0.102
NON EXCEED PROB    RECURRENCE INTERVAL    DISCHARGE
     0.0100              100.00              31.293
     0.0500               20.00              50.245
     0.1000               10.00              63.307
     0.2000                5.00              82.140
     0.5000                2.00             127.687
     0.8000                1.25             184.851
     0.9000                1.11             218.392
     0.9600                1.04             255.984
     0.9800                1.02             280.835
     0.9900                1.01             303.302
     0.9950                1.01             323.777
```

```
HURON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING MARCH 31                                  N =     57
  90  DAY LOW FLOW                                                                                       STATION  04174500
 INPUT DATA (ZERO VALUES OMITTED)
     300.000     367.000
     119.000      87.900     164.000
      32.500     112.000     165.000     181.000      97.300     161.000
      87.400     216.000      53.200     153.000     149.000     119.000     120.000     182.000
     219.000     231.000      89.500     170.000     118.000      86.300      97.600      53.300     135.000     105.000
      99.000     148.000     134.000     182.000     270.000     263.000     154.000      72.300     137.000     103.000
                             376.000     145.000     161.000     209.000     177.000     135.000     136.000     249.000
                                         230.000     226.000      70.500     149.000      80.500     158.000     140.000
                                                                             200.000                  95.000      92.900
 MEAN =          153.891
 VARIANCE =          5138.719
 STANDARD DEVIATION =          71.685
 SKEWNESS =          1.090
 STANDARD ERROR OF SKEWNESS =          0.316
 SERIAL CORRELATION COEFFICIENT =          0.323
 COEFFICIENT OF VARIATION =          0.466
 MEAN LOGS =          2.141
 VARIANCE LOGS =          0.043
 STANDARD DEVIATION LOGS =          0.207
 SKEWNESS LOGS =          -0.397
 STANDARD ERROR OF SKEWNESS LOGS =          0.316
 SERIAL CORRELATION COEFFICIENT LOGS =          0.229
 COEFFICIENT OF VARIATION LOGS =          0.097
 NON EXCEED PROB     RECURRENCE INTERVAL     DISCHARGE
         0.0100
         0.0500                  100.00
         0.1000                   20.00        39.865
         0.2000                   10.00        60.151
         0.5000                    5.00        73.940
         0.8000                    2.00        93.824
         0.9000                    1.25       142.872
         0.9600                    1.11       200.079
         0.9800                    1.04       248.978
         0.9900                    1.02       297.743
         0.9950                    1.01       331.990
                                   1.01       364.549
                                              395.725
```

```
HURON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING MARCH 31                    N =     57                    STATION  04174500
120  DAY LOW FLOW
INPUT DATA (ZERO VALUES OMITTED)
    306.000    366.000    185.000    225.000    106.000    180.000    132.000    218.000    143.000    119.000
    118.000     98.500    199.000    165.000    167.000    165.000    111.000     60.900    152.000    115.000
     41.900    119.000     74.400    189.000    119.000    104.000    160.000     90.600    151.000    276.000
     94.900    264.000    103.000    206.000    315.000    290.000    184.000    149.000    243.000    156.000
    253.000    298.000    147.000    155.000    176.000    221.000    159.000     86.800     98.900     97.500
    111.000    195.000    442.000    294.000    270.000     95.000    217.000
MEAN =        176.161
VARIANCE =        6571.602
STANDARD DEVIATION =        81.065
SKEWNESS =        0.984
STANDARD ERROR OF SKEWNESS =        0.316
SERIAL CORRELATION COEFFICIENT =        0.328
COEFFICIENT OF VARIATION =        0.463
MEAN LOGS =        2.199
VARIANCE LOGS =        0.041
STANDARD DEVIATION LOGS =        0.203
SKEWNESS LOGS =        -0.211
STANDARD ERROR OF SKEWNESS LOGS =        0.316
SERIAL CORRELATION COEFFICIENT LOGS =        0.276
COEFFICIENT OF VARIATION LOGS =        0.092
NON EXCEED PROB     RECURRENCE INTERVAL     DISCHARGE
     0.0100              100.00               49.665
     0.0500               20.00               71.306
     0.1000               10.00               86.056
     0.2000                5.00              107.266
     0.5000                2.00              160.567
     0.8000                1.25              234.035
     0.9000                1.11              283.060
     0.9600                1.04              345.146
     0.9800                1.02              390.160
     0.9900                1.01              434.602
     0.9950                1.01              478.734
```

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HURON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING MARCH 31                    N =     57                         STATION  04174500
183  DAY LOW FLOW

INPUT DATA (ZERO VALUES OMITTED)

     308.000      440.000      222.000      215.000      141.000      234.000      170.000      253.000      156.000      135.000
     129.000      153.000      270.000      223.000      195.000      233.000      132.000       91.700      191.000      135.000
      59.200      167.000      118.000      223.000      134.000      117.000      207.000      136.000      208.000      274.000
     117.000      273.000      135.000      228.000      407.000      308.000      237.000      171.000      390.000      206.000
     202.000      365.000      155.000      243.000      183.000      256.000      192.000      109.000      124.000      133.000
     147.000      250.000      530.000      307.000      342.000      128.000      280.000

MEAN =        215.226

VARIANCE =          9187.461

STANDARD DEVIATION =        95.851

SKEWNESS =        1.155

STANDARD ERROR OF SKEWNESS =        0.316

SERIAL CORRELATION COEFFICIENT =        0.280

COEFFICIENT OF VARIATION =        0.445

MEAN LOGS =        2.293

VARIANCE LOGS =        0.035

STANDARD DEVIATION LOGS =        0.187

SKEWNESS LOGS =        -0.010

STANDARD ERROR OF SKEWNESS LOGS =        0.316

SERIAL CORRELATION COEFFICIENT LOGS =        0.278

COEFFICIENT OF VARIATION LOGS =        0.082

NON EXCEED PROB    RECURRENCE INTERVAL    DISCHARGE

      0.0100              100.00            71.850
      0.0500               20.00            96.503
      0.1000               10.00           113.047
      0.2000                5.00           136.747
      0.5000                2.00           196.653
      0.8000                1.25           282.500
      0.9000                1.11           341.248
      0.9600                1.04           417.283
      0.9800                1.02           475.106
      0.9900                1.01           533.871
      0.9950                1.01           593.943
```

```
HURON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING MARCH 31                          N =     57                                STATION  04174500
365  DAY LOW FLOW

INPUT DATA (ZERO VALUES OMITTED)
      539.000     575.000     497.000     625.000     331.000     481.000     347.000     443.000     392.000     279.000
      296.000     378.000     481.000     390.000     372.000     567.000     252.000     204.000     336.000     274.000
      231.000     271.000     233.000     844.000     339.000     263.000     340.000     312.000     455.000     607.000
      295.000     513.000     246.000     621.000     843.000     668.000     442.000     358.000     581.000     354.000
      529.000     445.000     321.000     470.000     367.000     421.000     266.000     201.000     269.000     306.000
      320.000     462.000     701.000     567.000     632.000     264.000     546.000

MEAN =        413.368

VARIANCE =        20261.160

STANDARD DEVIATION =        142.342

SKEWNESS =        0.664

STANDARD ERROR OF SKEWNESS =        0.316

SERIAL CORRELATION COEFFICIENT =        0.316

COEFFICIENT OF VARIATION =        0.344

MEAN LOGS =        2.591

VARIANCE LOGS =        0.022

STANDARD DEVIATION LOGS =        0.149

SKEWNESS LOGS =        0.035

STANDARD ERROR OF SKEWNESS LOGS =        0.316

SERIAL CORRELATION COEFFICIENT LOGS =        0.302

COEFFICIENT OF VARIATION LOGS =        0.057

NON EXCEED PROB    RECURRENCE INTERVAL    DISCHARGE
     0.0100               100.00           177.621
     0.0500                20.00           223.070
     0.1000                10.00           252.067
     0.2000                 5.00           292.475
     0.5000                 2.00           389.552
     0.8000                 1.25           520.336
     0.9000                 1.11           606.039
     0.9600                 1.04           713.664
     0.9800                 1.02           793.535
     0.9900                 1.01           873.271
     0.9950                 1.01           953.502
```

```
HURON RIVER AT ANN ARBOR, MICH.                                    N =    58                    STATION  04174500
1915-1973,  12 MON PERIOD ENDING SEPTEMBER 30
   1  DAY HIGH FLOW
INPUT DATA (ZERO VALUES OMITTED)
      2050.000    3950.000    1670.000    5840.000    3090.000    2490.000    1140.000    3360.000    1230.000    1750.000
      1040.000    2950.000     927.000     942.000    1930.000    1820.000     467.000     957.000    1300.000    2590.000
      1160.000    1040.000    1960.000    2140.000    1920.000    1280.000     922.000    2090.000    3450.000    1300.000
      2090.000    1410.000    6170.000    3050.000    4170.000    2330.000    2090.000     928.000    1740.000    1820.000
      2690.000    1030.000    1090.000    2110.000    1680.000    2030.000    2500.000    1000.000     524.000    1020.000
      1150.000    1710.000    4010.000    2200.000    1240.000    2590.000    1120.000    1830.000
MEAN =       2011.672
VARIANCE =        1201260.00
STANDARD DEVIATION =        1096.020
SKEWNESS =          1.384
STANDARD ERROR OF SKEWNESS =          0.314
SERIAL CORRELATION COEFFICIENT =          0.093
COEFFICIENT OF VARIATION =          0.545
MEAN LOGS =          3.248
VARIANCE LOGS =          0.052
STANDARD DEVIATION LOGS =          0.228
SKEWNESS LOGS =        -0.050
STANDARD ERROR OF SKEWNESS LOGS =          0.314
SERIAL CORRELATION COEFFICIENT LOGS =          0.112
COEFFICIENT OF VARIATION LOGS =          0.070
EXCEEDENCE PROB     RECURRENCE INTERVAL     DISCHARGE
      0.9900                    1.01          509.378
      0.9500                    1.05          737.030
      0.9000                    1.11          895.950
      0.8000                    1.25         1133.155
      0.5000                    2.00         1767.527
      0.2000                    5.00         2740.123
      0.1000                   10.00         3437.461
      0.0400                   25.00         4369.660
      0.0200                   50.00         5097.234
      0.0100                  100.00         5850.715
      0.0050                  200.00         6633.840
```

```
HURON RIVER AT ANN ARBOR, MICH.                                       N =    58                        STATION  04174500
1915-1973,  12 MON PERIOD ENDING SEPTEMBER 30
  3  DAY HIGH FLOW
INPUT DATA (ZERO VALUES OMITTED)
     1750.000     3560.000     1550.000     4530.000     2820.000     2350.000     1060.000     2980.000     1150.000     1530.000
      937.000     2730.000      899.000      939.000     1700.000     1770.000      488.000      879.000     1240.000     2110.000
      944.000      960.000     1630.000     1960.000     1800.000     1230.000      861.000     1830.000     3180.000     1190.000
     2600.000     1360.000     4900.000     2430.000     3940.000     2270.000     1870.000      835.000     1530.000     1600.000
     2650.000      934.000      993.000     1870.000     1660.000     1820.000     2200.000      963.000      503.000     1540.000
     1090.000     1400.000     3600.000     2010.000     1180.000     2290.000     1040.000     1750.000

MEAN =      1819.224
VARIANCE =        919650.187
STANDARD DEVIATION =        958.984
SKEWNESS =          1.286
STANDARD ERROR OF SKEWNESS =          0.314
SERIAL CORRELATION COEFFICIENT =          -0.081
COEFFICIENT OF VARIATION =          0.527
MEAN LOGS =          3.208
VARIANCE LOGS =          0.049
STANDARD DEVIATION LOGS =          0.220
SKEWNESS LOGS =       -0.009
STANDARD ERROR OF SKEWNESS LOGS =          0.314
SERIAL CORRELATION COEFFICIENT LOGS =          0.114
COEFFICIENT OF VARIATION LOGS =          0.069
EXCEEDENCE PROB    RECURRENCE INTERVAL    DISCHARGE
     0.9900                     1.01          491.487
     0.9500                     1.05          695.014
     0.9000                     1.11          837.249
     0.8000                     1.25         1047.252
     0.5000                     2.00         1605.624
     0.2000                     5.00         2459.125
     0.1000                    10.00         3071.668
     0.0400                    25.00         3892.658
     0.0200                    50.00         4535.516
     0.0100                   100.00         5203.303
     0.0050                   200.00         5899.898
```

```
HURON RIVER AT ANN ARBOR, MICH.                                     N =    58                    STATION  04174500
1915-1973,  12 MON PERIOD ENDING SEPTEMBER 30
  7  DAY HIGH FLOW

INPUT DATA (ZERO VALUES OMITTED)

     1530.000     3510.000     1320.000     3000.000     2430.000     2090.000      990.000     2450.000     1040.000     1200.000
      820.000     2390.000      852.000      910.000     1510.000     1760.000      433.000      725.000     1170.000     1770.000
      873.000      934.000     1450.000     1730.000     1690.000     1150.000      804.000     1610.000     2900.000     1120.000
     2260.000     1310.000     4680.000     2110.000     3410.000     2120.000     1640.000      775.000     1350.000     1400.000
     2610.000      861.000      936.000     1590.000     1600.000     1580.000     1760.000      948.000      463.000     1290.000
      890.000     1300.000     3160.000     1710.000     1130.000     1870.000      961.000     1710.000

MEAN =      1626.431

VARIANCE =      730160.500

STANDARD DEVIATION =       854.494

SKEWNESS =          1.445

STANDARD ERROR OF SKEWNESS =        0.314

SERIAL CORRELATION COEFFICIENT =        0.082

COEFFICIENT OF VARIATION =        0.525

MEAN LOGS =       3.159

VARIANCE LOGS =        0.046

STANDARD DEVIATION LOGS =        0.214

SKEWNESS LOGS =        0.067

STANDARD ERROR OF SKEWNESS LOGS =        0.314

SERIAL CORRELATION COEFFICIENT LOGS =        0.134

COEFFICIENT OF VARIATION LOGS =        0.068

EXCEEDENCE PROB    RECURRENCE INTERVAL    DISCHARGE

      0.9900                 1.01         469.177
      0.9500                 1.05         646.860
      0.9000                 1.11         769.227
      0.8000                 1.25         950.617
      0.5000                 2.00        1433.803
      0.2000                 5.00        2179.543
      0.1000                10.00        2721.484
      0.0400                25.00        3456.930
      0.0200                50.00        4039.930
      0.0100               100.00        4652.012
      0.0050               200.00        5297.031
```

```
MUHON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING SEPTEMBER 30                               N =    58                              STATION  04174500
  15  DAY HIGH FLOW
  INPUT DATA (ZERO VALUES OMITTED)
      1500.000     2030.000     1130.000     2840.000     1940.000     1840.000      896.000     2000.000      953.000     1010.000
       678.000     2190.000      823.000      891.000     1370.000     1510.000      396.000      613.000     1090.000     1370.000
       801.000      897.000     1290.000     1520.000     1410.000     1050.000      609.000     1560.000     2830.000     1050.000
      1870.000     1200.000     3540.000     1840.000     3170.000     1960.000     1450.000      730.000     1200.000     1220.000
      2320.000      775.000      883.000     1440.000     1400.000     1310.000     1600.000      898.000      448.000     1080.000
       721.000     1210.000     2380.000     1340.000      981.000     1560.000      854.000     1630.000
  MEAN =        1413.396
  VARIANCE =        463308.312
  STANDARD DEVIATION =         680.667
  SKEWNESS =         1.186
  STANDARD ERROR OF SKEWNESS =         0.314
  SERIAL CORRELATION COEFFICIENT =         0.104
  COEFFICIENT OF VARIATION =         0.482
  MEAN LOGS =         3.104
  VARIANCE LOGS =         0.041
  STANDARD DEVIATION LOGS =         0.202
  SKEWNESS LOGS =        -0.022
  STANDARD ERROR OF SKEWNESS LOGS =         0.314
  SERIAL CORRELATION COEFFICIENT LOGS =         0.146
  COEFFICIENT OF VARIATION LOGS =         0.065
  EXCEEDENCE PROB     RECURRENCE INTERVAL     DISCHARGE
      0.9900                  1.01              486.903
      0.9500                  1.05              589.112
      0.9000                  1.11              699.001
      0.8000                  1.25              859.337
      0.5000                  2.00             1273.340
      0.2000                  5.00             1882.329
      0.1000                 10.00             2306.854
      0.0400                 25.00             2863.535
      0.0200                 50.00             3291.417
      0.0100                100.00             3729.696
      0.0050                200.00             4180.067
```

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```
HURON RIVER AT ANN ARBOR, MICH.
1915-1973,  12 MON PERIOD ENDING SEPTEMBER 30                         N =     58                              STATION  04174500
  30  DAY HIGH FLOW

 INPUT DATA (ZERO VALUES OMITTED)
     1200.000     2030.000     1030.000     2630.000     1630.000     1350.000      850.000     1640.000      836.000      934.000
      607.000     2050.000      724.000      820.000     1270.000     1150.000      346.000      853.000      898.000      990.000
      689.000      794.000     1050.000     1310.000     1070.000      845.000      610.000     1250.000     2650.000      935.000
     1470.000      997.000     2650.000     1340.000     2470.000     1050.000     1350.000      603.000     1050.000     1110.000
     2040.000      647.000      683.000     1280.000     1260.000     1060.000     1220.000      723.000      399.000      894.000
      580.000     1000.000     1590.000     1200.000      899.000     1270.000      739.000     1510.000

MEAN =       1181.683
VARIANCE =       296795.750
STANDARD DEVIATION =        544.790
SKEWNESS =          1.214
STANDARD ERROR OF SKEWNESS =          0.314
SERIAL CORRELATION COEFFICIENT =          0.087
COEFFICIENT OF VARIATION =          0.461
MEAN LOGS =          3.031
VARIANCE LOGS =          0.037
STANDARD DEVIATION LOGS =          0.192
SKEWNESS LOGS =          0.003
STANDARD ERROR OF SKEWNESS LOGS =          0.314
SERIAL CORRELATION COEFFICIENT LOGS =          0.156
COEFFICIENT OF VARIATION LOGS =          0.063
EXCEEDENCE PROB     RECURRENCE INTERVAL     DISCHARGE
     0.9900                  1.01            384.022
     0.9500                  1.05            510.772
     0.9000                  1.11            609.041
     0.8000                  1.25            739.684
     0.5000                  2.00           1073.050
     0.2000                  5.00           1557.174
     0.1000                 10.00           1092.026
     0.0400                 25.00           2329.046
     0.0200                 50.00           2663.009
     0.0100                100.00           3005.957
     0.0050                200.00           3357.570
```

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```
HURON RIVER AT ANN ARBOR, MICH.                                    N =    58                         STATION  04174500
1915-1973,  12 MON PERIOD ENDING SEPTEMBER 30
  60  DAY HIGH FLOW

INPUT DATA (ZERO VALUES OMITTED)

     881.000    1520.000     907.000    1910.000    1410.000    1060.000     790.000    1240.000     652.000     827.000
     306.000    1480.000     497.000     716.000    1160.000    1030.000     290.000     466.000     844.000     620.000
     610.000     600.000     855.000    1180.000     970.000     604.000     526.000     972.000    1750.000     849.000
    1010.000     763.000    1930.000    1150.000    1990.000    1390.000    1210.000     664.000     982.000     924.000
    1390.000     627.000     612.000    1150.000     920.000     777.000     839.000     547.000     382.000     838.000
     502.000     841.000    1230.000    1160.000     800.000    1030.000     679.000    1210.000

MEAN =        956.086

VARIANCE =       146168.675

STANDARD DEVIATION =       382.320

SKEWNESS =         0.895

STANDARD ERROR OF SKEWNESS =        0.314

SERIAL CORRELATION COEFFICIENT =        0.195

COEFFICIENT OF VARIATION =        0.400

MEAN LOGS =        2.947

VARIANCE LOGS =         0.030

STANDARD DEVIATION LOGS =        0.174

SKEWNESS LOGS =         -0.180

STANDARD ERROR OF SKEWNESS LOGS =        0.314

SERIAL CORRELATION COEFFICIENT LOGS =        0.233

COEFFICIENT OF VARIATION LOGS =        0.059

EXCEEDENCE PROB    RECURRENCE INTERVAL    DISCHARGE

      0.9900                 1.01          330.352
      0.9500                 1.05          448.600
      0.9000                 1.11          525.718
      0.8000                 1.25          634.135
      0.5000                 2.00          895.808
      0.2000                 5.00         1244.114
      0.1000                10.00         1467.302
      0.0400                25.00         1740.906
      0.0200                50.00         1938.969
      0.0100               100.00         2132.476
      0.0050               200.00         2323.019
```

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```
HURON RIVER AT ANN ARBOR, MICH.                                              N =    50                         STATION  04174500
1915-1973,  12 MON PERIOD ENDING SEPTEMBER 30
 90  DAY HIGH FLOW

INPUT DATA (ZERO VALUES OMITTED)

      723.000     1310.000      812.000     1440.000     1140.000      837.000      640.000     1070.000      549.000      708.000
      433.000     1150.000      611.000      672.000     1140.000      932.000      273.000      447.000      741.000      466.000
      470.000      563.000      825.000     1020.000      896.000      510.000      457.000      761.000     1460.000      808.000
      853.000      675.000     1630.000     1010.000     1720.000     1260.000     1130.000      616.000      944.000      808.000
     1300.000      600.000      547.000      986.000      808.000      690.000      678.000      485.000      334.000      756.000
      477.000      695.000     1040.000     1090.000      741.000      856.000      606.000     1060.000

MEAN =        832.052

VARIANCE =        101770.187

STANDARD DEVIATION =        319.014

SKEWNESS =         0.744

STANDARD ERROR OF SKEWNESS =          0.314

SERIAL CORRELATION COEFFICIENT =          0.214

COEFFICIENT OF VARIATION =          0.383

MEAN LOGS =         2.889

VARIANCE LOGS =          0.029

STANDARD DEVIATION LOGS =          0.169

SKEWNESS LOGS =         -0.217

STANDARD ERROR OF SKEWNESS LOGS =          0.314

SERIAL CORRELATION COEFFICIENT LOGS =          0.246

COEFFICIENT OF VARIATION LOGS =          0.059

EXCEEDENCE PROB    RECURRENCE INTERVAL    DISCHARGE

      0.9900                  1.01          293.887
      0.9500                  1.05          398.325
      0.9000                  1.11          465.813
      0.8000                  1.25          560.132
      0.5000                  2.00          784.814
      0.2000                  5.00         1077.983
      0.1000                 10.00         1262.667
      0.0400                 25.00         1485.998
      0.0200                 50.00         1645.700
      0.0100                100.00         1800.228
      0.0050                200.00         1951.006
```

```
HURON RIVER AT ANN ARBOR, MICH.                          N =     58                          STATION  04174500
1916-1973,  12 MON PERIOD ENDING SEPTEMBER 30
120  DAY HIGH FLOW

INPUT DATA (ZERO VALUES OMITTED)

     632.000    1170.000     761.000    1160.000     937.000     692.000     548.000     904.000     460.000     625.000
     364.000     958.000     552.000     627.000     956.000     899.000     266.000     435.000     664.000     396.000
     443.000     461.000     734.000     872.000     742.000     464.000     470.000     658.000    1350.000     712.000
     789.000     592.000    1360.000     925.000    1590.000    1160.000    1090.000     559.000     799.000     780.000
    1130.000     569.000     497.000     840.000     797.000     607.000     584.000     438.000     301.000     642.000
     431.000     627.000     947.000     979.000     460.000     719.000     515.000     999.000

MEAN =        738.069

VARIANCE =        78153.000

STANDARD DEVIATION =        279.559

SKEWNESS =        0.809

STANDARD ERROR OF SKEWNESS =        0.314

SERIAL CORRELATION COEFFICIENT =        0.256

COEFFICIENT OF VARIATION =        0.379

MEAN LOGS =        2.838

VARIANCE LOGS =        0.027

STANDARD DEVIATION LOGS =        0.165

SKEWNESS LOGS =        -0.134

STANDARD ERROR OF SKEWNESS LOGS =        0.314

SERIAL CORRELATION COEFFICIENT LOGS =        0.263

COEFFICIENT OF VARIATION LOGS =        0.058

EXCEEDENCE PROB     RECURRENCE INTERVAL     DISCHARGE

      0.9900                    1.01          273.995
      0.9500                    1.05          363.314
      0.9000                    1.11          420.883
      0.8000                    1.25          501.393
      0.5000                    2.00          694.320
      0.2000                    5.00          950.003
      0.1000                   10.00         1113.893
      0.0400                   25.00         1315.270
      0.0200                   50.00         1461.510
      0.0100                  100.00         1604.834
      0.0050                  200.00         1746.439
```

```
HURON RIVER AT ANN ARBOR, MICH.                                  N =     58                          STATION  04174500

1915-1973,  12 MON PERIOD ENDING SEPTEMBER 30

183  DAY HIGH FLOW

INPUT DATA (ZERO VALUES OMITTED)

     549.000   1040.000    609.000    823.000    750.000    538.000    504.000    799.000    368.000    509.000
     290.000    810.000    487.000    596.000    742.000    745.000    235.000    400.000    594.000    334.000
     362.000    387.000    611.000    686.000    571.000    363.000    436.000    530.000   1130.000    563.000
     589.000    497.000   1010.000    758.000   1320.000   1110.000    937.000    514.000    641.000    749.000
     860.000    534.000    472.000    625.000    716.000    458.000    496.000    343.000    259.000    500.000
     423.000    540.000    897.000    909.000    551.000    657.000    460.000    915.000

MEAN =        622.431

VARIANCE =        53839.277

STANDARD DEVIATION =       232.033

SKEWNESS =        0.807

STANDARD ERROR OF SKEWNESS =        0.314

SERIAL CORRELATION COEFFICIENT =        0.297

COEFFICIENT OF VARIATION =        0.373

MEAN LOGS =        2.765

VARIANCE LOGS =        0.026

STANDARD DEVIATION LOGS =        0.162

SKEWNESS LOGS =       -0.130

STANDARD ERROR OF SKEWNESS LOGS =        0.314

SERIAL CORRELATION COEFFICIENT LOGS =        0.202

COEFFICIENT OF VARIATION LOGS =        0.059

EXCEEDENCE PROB    RECURRENCE INTERVAL    DISCHARGE

     0.9900               1.01              235.691
     0.9500               1.05              310.725
     0.9000               1.11              358.919
     0.8000               1.25              426.148
     0.5000               2.00              586.644
     0.2000               5.00              798.446
     0.1000              10.00              933.840
     0.0400              25.00             1099.910
     0.0200              50.00             1220.350
     0.0100             100.00             1338.286
     0.0050             200.00             1454.719
```

```
HURON RIVER AT ANN ARBOR, MICH.                       N =     58                        STATION  04174500

1915-1973,  12 MON PERIOD ENDING SEPTEMBER 30

365  DAY HIGH FLOW

INPUT DATA (ZERO VALUES OMITTED)

      474.000      680.000      421.000      497.000      476.000      372.000      358.000      517.000      255.000      343.000
      200.000      342.000      380.000      408.000      465.000      468.000      171.000      270.000      379.000      206.000
      237.000      244.000      423.000      427.000      345.000      254.000      293.000      349.000      717.000      382.000
      371.000      351.000      633.000      493.000      812.000      740.000      635.000      367.000      402.000      514.000
      565.000      395.000      324.000      404.000      520.000      338.000      344.000      258.000      166.000      306.000
      284.000      371.000      678.000      678.000      421.000      418.000      333.000      675.000

MEAN =        420.155

VARIANCE =        22535.227

STANDARD DEVIATION =        150.117

SKEWNESS =        0.686

STANDARD ERROR OF SKEWNESS =        0.314

SERIAL CORRELATION COEFFICIENT =        0.381

COEFFICIENT OF VARIATION =        0.357

MEAN LOGS =        2.596

VARIANCE LOGS =        0.025

STANDARD DEVIATION LOGS =        0.157

SKEWNESS LOGS =     -0.150

STANDARD ERROR OF SKEWNESS LOGS =        0.314

SERIAL CORRELATION COEFFICIENT LOGS =        0.384

COEFFICIENT OF VARIATION LOGS =        0.060

EXCEEDENCE PROB     RECURRENCE INTERVAL     DISCHARGE

      0.9900                     1.01        163.986
      0.9500                     1.05        214.870
      0.9000                     1.11        247.294
      0.8000                     1.25        292.220
      0.5000                     2.00        398.219
      0.2000                     5.00        535.827
      0.1000                    10.00        622.634
      0.0400                    25.00        720.031
      0.0200                    50.00        803.797
      0.0100                   100.00        877.476
      0.0050                   200.00        949.755
```

APPENDIX IV

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72013

GENERAL CONSIDERATIONS IN THE DESIGN OF A FLOOD CONTROL RETENTION BASIN TO IMPROVE THE WATER QUALITY CONTROL CAPABILITY

March, 1981

Environmental Control Technology Corporation
3983 Research Park Drive
Ann Arbor, Michigan 48104

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GENERAL CONSIDERATIONS IN THE DESIGN OF A FLOOD CONTROL RETENTION BASIN TO IMPROVE THE WATER QUALITY CONTROL CAPABILITY

GENERAL DESIGN CONSIDERATION

There are many variables which can affect a retention basin's ability to control suspended solids and associated pollutants. Some of the variables such as particle size and characteristics, sediment load, and general hydrograph shape are basic variables which must be accepted as site specific conditions. Design features such as inlet design, basin geometry, and outlet design are the variables which can be controlled and tailored to control the site specific variables. These designs should be selected to enhance the trapping efficiency of the basin and reflect the design goal of controlling suspended solids to the largest extent practical within the restraints of a given area and project.

Storm water runoff varies greatly in runoff rate and solids concentration. Thus it is more difficult to select a design basis for sedimentation for storm runoff than it is for water or wastewater treatment. The greatly varying flow rates presents certain difficulties in the inlet and outlet designs and can greatly affect the basin response as depths and surface area will vary considerably over a given storm event. Thus in selecting design goals the target removal rates either in terms of percent removal and/or smallest particle to be captured must be considered for a given set of conditions. The actual performance of the basin will vary based on the actual experienced conditions.

Even though stormwater characteristics are highly variable and difficult to predict, the basic theory of sedimentation applies to the basin design. Thus, factors such as surface area, detention time, short circuiting, inlet and outlet characteristics will all play a role in the settling characteristics of the basin. Several items which should be considered in designing the inlet structure, basin size, and outlet structure are presented below. The specific details of which concepts can be incorporated into the final design can best be done by the design engineer in his/her final design studies. Knowledge of the topography of the area, hydraulic conditions of the channel and requirements for flood control (i.e. allowable outlet rate, inlet rate, etc.) will in many cases dictate the applicability of a specific type of approach. It is recommended that the final design incorporate as many of the features which enhance settling as possible and which are within the flood control and cost restraints of this project.

INLET STRUCTURE/CONDITIONS

The design of the inlet structure to a basin should reflect the need to maximize the settling of suspended materials. Two key considerations in designing an inlet structure are the placement or location of the inlet in relationship to the outlet structure, and the method in which the inlet structure introduces the water to the basin. These considerations are based on controlling the physical conditions which affect sedimentation, namely, minimizing short circuiting in the basin and minimizing turbulence within the basin.

Proper placement and orientation of the inlet structure will minimize the short circuiting problem of the settling basin and tend to maximize the time a given "drop" of water is held in the basin. The inlet should be positioned away from the outlet point so that the entire basin can be used effectively. Many existing basins have the inlet and outlet points immediately adjacent to each other. During small storms this design results in water passing directly from the inlet to the outlet without obtaining the benefit of being held in the main portion of the basin. Placing the structure on the opposite side of the basin or in another orientation may increase the potential for sedimentation to occur. Some flood control basins have the inlet structure at 90° from the outlet and pointed at the outlet. Reorientation of the inlet to point away from the outlet point can again help to maximize the sedimentation process. These types of design modifications can generally be accomplished very easily at the design stage of the project and result in little or no additional cost.

In addition, consideration should be given to the method used to introduce the water to the basin. Water flowing from the structure should not induce heavy turbulence or cause erosion in the vicinity of the inlet structure. The inlet design should consider energy dissipation methods commonly used in structure design and should consider distribution of the water as it flows into the basin. Careful design of the inlet, together with appropriate contouring of the basin in the inlet vicinity, can greatly improve the entrance characteristics and help to maximize water quality control.

BASIN SIZE

The minimum detention basin size must be based on the volume of water to be stored in order to control peak runoff rates and prevent downstream flooding. The size of the basin should also be based on providing a specified detention time for a given volume storm. The detention in the basin is a primary factor in determining the sediment trap efficiency of the basin. In order to determine the detention time, a target level of performance for suspended solids can be set. At this time a reasonable level of performance to consider would be removing all particles of silt size (5 to 10 micron and larger) for storm volumes of up to the one-year storm level. This criteria provides a starting point for consideration of basin size and outlet rate.

The average settling velocity for the median size particle (27.5 micron) is 0.0675 cm/sec. using Stokes Law. This value can be utilized with the peak flow rate based on the hydraulics and final design to determine the minimum required surface area of the basin to allow flow-through velocity to be smaller than the settling velocity of the median particle.

The detention time of water in the basin will vary with the size of the storm and the design of the outlet structure. Average detention time will also vary depending on whether the basin is designed dry or wet (i.e. empty following a rain as opposed to a permanent pond). Current research indicates wet retention basins may provide more effective control than dry basins. This may be due, however, to the fact that wet basins generally provide more detention time for small storms (which are numerous) as opposed to a dry basin. This detention time differential could be reduced by altering the typical outlet structure design of a dry basin to increase the detention time for small storms. Another consideration in a dry basin design is the problem of solids resuspending when the basin receives water during a storm. The contour of the basin and pathway of low volume storms through the basin must be considered to minimize the amount of material which may be resuspended. It also is important to consider the type of cover present in the bottom of the basin. Exposed, non-stabilized soil in the bottom of a dry basin would allow for the potential of erosion to occur. Thus, careful thought must be given to the design of the basin itself to help maximize the sedimentation process.

Basin design should also consider the need for periodic cleanout. Assuming the design is undertaken to maximize the retention of solids, periodic removal of these solids will be required. The basin design should allow for ease of access for dredging equipment and trucks to remove these solids. It may be possible to dispose of the sediment buildup in the vicinity of the basin. If this is not possible, provisions for removal to another location must be considered.

OUTLET STRUCTURE

The outlet structure is the controlling mechanism for outflow, and therefore will control the detention time and volume of water stored for any given storm event hydrograph. The outlet structure should allow a variable discharge rate so that large volume storms diverted to the basin will discharge in a reasonable period of time (as an example, all water should be discharged within 24 hours following a rain event to maintain a dry basin concept). This variable discharge rate does not generally cause any difficulty because flow rate increases through most control devices as the depth of water in the basin increases. In the design of an outlet structure a special consideration of the low runoff volume storm is required if adequate settling time is to be provided for the small event. The sizing of the outlet structure so that low runoff volume storms are detained for a sufficient length of time is absolutely necessary if the basin is to trap solids during these events.

There are several types of outlets which can be utilized in a basin of this type. Two methods which are receiving more widespread use today with good success rates are perforated riser pipes with varying size holes for controlling flow and underdrain perforated pipe systems with a porous cover and fixed height overflow pipe. The use of a perforated riser pipe or the use of a perforated riser pipe in conjunction with a small underdrain system to ensure all water drains from the basin, appear quite feasible for most basins and could provide necessary flow rate controls. In order for this device to maximize sediment trap efficiency and minimize problems of clogging, a porous media filter can be placed around the riser pipe.

As mentioned earlier, the diversion of smaller storms will affect the capacity of the detention area for control of flooding problems. A blending of the needs for flood control and water quality control is required in the final design. A potential problem, which will depend on the hydraulics, topography, rainfall patterns, etc., is that the diversion of all of the initial flow from a large storm (i.e. one-year storm) may utilize a large portion of the capacity of the basin prior to the occurrence of the peak flow associated with the 10-year storm (basis for flood control). Special design considerations may be required to ensure that the 10-year peak flow is stored in the basin. An example might be the use of an outlet structure designed to handle the one-year storm as outlined above. Flow about this level would be allowed to discharge at a higher rate up to the maximum allowable rate to control flooding. A method such as this would control the one-year storm but allow larger storms to pass through the basin with a lower overall detention time. The actual allowable discharge rate to prevent flooding is set by the final design and will be a primary factor in determining final outlet configuration.

Depending on the geometry of the basin at various stages and within the topography of the land, it may be helpful to baffle or distribute the flow as it reaches the outlet structure. This may be required to minimize the possibility of scouring and/or depositing large amounts of solids at the outlet structure.

MAINTENANCE

Once the detention basin is constructed and becomes operational, maintenance will be required to assure the proper functioning of the basin. The importance of maintaining the detention area cannot be overemphasized. Periodic checks of the inlet and outlet structures to ensure they are free of debris and functioning properly are essential. Measurements of sediment buildup must also be performed on a routine basis to ensure that sediment does not remove a substantial amount of the basin sediment storage capacity. Gravel or other porous filter media used to protect the outlet structure must be checked to ensure that proper flow-through conditions are occurring. Any baffle-like or flow-diversion type structures in the basin must be kept clean and functioning.

The actual time requirements for maintaining the basin will depend on the nature of the designed structures and on the actual experienced sediment buildup rate. The need for routine maintenance is somewhat contrary to the past approach to stormwater systems. Past work has attempted to design "self-cleaning" type systems requiring little or no maintenance. Concepts for controlling water quality work in the opposite direction. The goals are to trap and retain as much of the pollutants as possible. The result of this change is that routine checks and maintenance become an important part of the control system. If maintenance is not provided in the total drainage basin plan, the water quality control measures can eventually worsen the pollution problems rather than control them. Thus, if maintenance is not planned and provided for, in many cases it may be better to forego water quality control measures rather than install them, maintain them less often than necessary, and permit them to malfunction. Proper design and maintenance programs of control techniques, however, can provide valuable benefits to the total drainage system and the river.